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CHEMICAL FACTORS IN NUTRITION.*

BY

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When the food which we ingest starts on its way along the path of the alimentary tract it is ordinarily regarded as having entered the body. It does, in truth, disappear from sight as soon as it has passed beyond the mouth and into the deeper recesses of the organism; but every one who is familiar with the structure of the long gastro-intestinal tube—the digestive canal—realizes that the walls of the latter offer a pronounced barrier to the ready transport of the swallowed food materials to the various tissues and organs where it may be needed. To follow the nutrients into the stomach and upper intestine is comparatively easy; far more difficult, however, is the task of tracing their passage through the thick walls of the alimentary tract into the lymph and bloodstreams wherein they are distributed far and wide in the body.

Insoluble food particles obviously cannot permeate the mucous membrane that lines the enteric tract. The older physiologists, who concerned themselves not at all with the problem of how such solid nutriment is made available, were content to assume that in some way it must become soluble so that it can filter or diffuse through the gastro-intestinal wall. Some sort of digestion was thus conceived to be essential to absorption in the case of insoluble products such as much of an ordinary meal represents. For a long time it was vigorously debated whether digestion in the

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stomach, and perhaps beyond, was not secured by mechanical trituration of the food or by some fermentative processes. It redounds to the credit of the progress of science in America that this country early furnished one of the great classics in the study of physiology of digestion. The pioneer investigations of Dr. William Beaumont on Alexis St. Martin, the man with "the lid on his stomach," helped to elucidate the nature of the gastric juice and establish the fact that it is an "agent of chymification" which "acts as a solvent of food and alters its properties." Experiment thus replaced conjecture.

The familiar foodstuffs—the proteins, fats and carbohydrates—which in large measure compose our food, are not simple chemical substances; they are for the most part rather complex compounds. With the development of the physiological chemistry of digestion has come the growing recognition that all the foodstuffs not merely are dissolved, but are further chemically disintegrated before they experience absorption. This profound cleavage of the nutrients into relatively simple fragments is accomplished by the unique potency of the digestive juices. In my own student days it sufficed to believe that the digestion of proteins, accomplished by the proteolytic enzymes or ferments of the gastric and pancreatic secretions, transformed the albuminous substances into proteoses and peptones, still essentially protein in nature except for a greater diffusibility, and perhaps to a smaller extent into a few then recognized amino-acids. Foster's "Text-book of Physiology," a popular treatise of a quarter of a century ago, stated:

> In all events the greater part of the proteid material of the food enters the blood as proteid material either as peptone or in some other form, and is carried as proteid material to the tissues. * * * The evidence as far as it goes tends to show that the metabolism of proteid is very complex and varied, that a large number of nitrogen-holding substances make a momentary appearance in the body, taking origin at this or that step in the downward steps of katabolic metabolism and changing into something else at the next step, and that the presence in various parts of the body and even in the urine, in small quantities, of so many varied nitrogenous crystalline substances, forming a large part of what are known as extractives, has to do with this varied metabolism. Possibly the transformations by which nitrogen thus passes downward take place to a certain extent in such organs as the liver and the spleen, which are remarkably rich in these extractives. But the whole story of proteid metabolism consists at present mostly of guesses and of gaps.

To-day there is added the knowledge of the further peculiar proteolytic power of the intestinal secretion, with the possibility

of a more or less complete disintegration of proteins into their constituent amino-acids prior to absorption. So, too, the fats are digested, not merely dissolved or absorbed in particulate form; and the carbohydrates pass through the alimentary wall as simple monosaccharide compounds. The true nutrient units discoverable after absorption in the blood-stream are comparatively simple chemical compounds rather than the complex food substances which we ordinarily ingest. Hence there is a significant truth in the recent statement that "the tissue cells never know the food which we eat." Digestion, profound in its chemical cleavages, is recognized as the indispensable forerunner of absorption.

The outcome of the digestive disintegration of the ingested foodstuffs is, therefore, somewhat different from what one would have assumed only a few years ago. The ultimate sources of energy for the organism start as relatively simple chemical compounds on the path of distribution to the places where they are required for fuel or constructive enterprises. Amino-acids, other nitrogenous units like purins or nucleosides, simple sugars, and fats represent the particular types of matter that enter the transportation routes of the circulation. Sometimes they are built selectively into desired structures—into tissue fabrics or components of secretion; sometimes they are stored in special depots as fat or glycogen or protein to await a future demand for these reserves; sometimes they are at once consumed or, to quote the term used by the physiologist, they are metabolized.

The various aspects of life, like other activities in the world about us, represent a transformation of matter and energy. Our organism builds up and in turn wears out its structural parts, it utilizes food fuel somewhat as non-living mechanisms employ coal, wood, oil or gas. From this general standpoint the preceding review of the preparation of our food for distribution and subsequent use is not difficult to appreciate. It is only when the subtle details are contemplated that the innumerable intricate problems of nutrition present themselves. How does the organism build the absorbed nutrient units into suitable anatomical structures, or how does it transform them so that work is done and heat produced? The analogies of the steam engine with its fire box and fuel and air supply leave us in the lurch when we attempt to institute a strict comparison with the living organism. Indeed it may as well be admitted that the complete history of the physio-

logical metabolism of matter is still obscure and unrevealed. From time to time, however, new details have come to light, revealing some of the secrets of the chemical processes upon which life depends. Let us turn our attention to a few of these.

There are organisms which can satisfy their biological needs with a comparatively few substances of relatively simple character. Thus the yeast plant can be made to grow and complete its life cycle in a medium that furnishes only comparatively simple compounds—a little pure sugar, nitrogen in the form of ammonium sulphate, along with phosphates and chlorides of potassium, calcium, and magnesium. Development under these circumstances means profound chemical synthesis. The yeast organism builds up highly complex proteins, fats, carbohydrates, nucleic acid and presumably a multitude of as yet unrecognized compounds into the tiny cells that seem so simple and relatively undifferentiated to an observer through the microscope. Plants in general possess such remarkable powers of synthesis—mysterious and never failing in their wonders. The carbon dioxid of the air suffices to furnish carbon for most elaborate structures. Such well-recognized atmospheric sources of plant nutriment were scarcely dreamed of by the older investigators who searched for a "principle" of vegetation to account for the phenomena of soil fertility and plant growth. Van Helmont considered he had found it in water, and thus records his famous Brussels experiment:

> I took an earthen vessel in which I put 200 pounds of soil dried in an oven; then I moistened with rain water and pressed hard into it a shoot of willow weighing 5 pounds. After exactly five years the tree that had grown up weighed 169 pounds and about 3 ounces. But the vessel had never received anything but rain water or distilled water to moisten the soil when this was necessary, and it remained full of soil which was still tightly packed, and, lest any dust from outside should get into the soil, it was covered with a sheet of iron coated with tin, but perforated with many holes. I did not take the weight of the leaves that fell in the autumn. In the end I dried the soil once more and got the same 200 pounds that I started with, less about two ounces. Therefore the 164 pounds of wood, bark, and root arose from the water alone.

The animal organisms, on the other hand, are not endowed with capacities for constructive work equal to those possessed by plants. It is not merely nitrogen, carbon and oxygen in some simple groupings that they require to be elaborated by them synthetically into brain and muscle and gland components. The powers of synthesis in animals are limited. Bathed though they

continually are in a sea of nitrogen, they cannot utilize it to produce nitrogenous tissues. There are certain structural units which the animal cannot manufacture *de novo*. Unless these are supplied as such, growth, tissue construction and repair are limited to the available supply of the essential parts.

The evidence for this conclusion forms a comparatively recent chapter in the study of nutrition. The nitrogenous needs of an animal can be supplied by the inclusion of protein in the diet. The newer chemistry of the proteins has brought unexpected revelations regarding their intimate structure and has thereby completely altered the traditional views regarding their physiological behavior. It has been demonstrated that, in general, the proteins are complexes which yield eighteen or more amino-acids that have become prominent items of interest to the student of nutrition. The proteins from different sources, and likewise the different proteins from a single plant or animal tissue, may vary in respect to the proportions of the characteristic amino-acids—the constructive units or " building stones " out of which they are built up. Some fail to yield one or more of the amino-acids usually obtainable from proteins. In this sense they are sometimes spoken of as " incomplete " proteins. For example, of the usually obtained representatives, the protein zein of the maize kernel fails to yield either glycocoll, lysine, or tryptophane; the gliadin of wheat is comparatively poor in its contribution of lysine and extremely rich in the glutaminic acid group; the gelatin derived from connective tissue lacks the tyrosine, tryptophane and sulphur-containing cystine groups.

With the possibility of such inequalities in the protein intake presented to the organism, how are we to conceive of the production or maintenance of blood- or muscle- or nerve-protein having the unvarying and specific chemical character that biological experience leads us to expect? For the answer to this question the modern chemistry of digestion has given a clue scarcely anticipated a generation ago. It has demonstrated that the various proteins are disintegrated in the digestive processes into their constituent amino-acid groups. It is, for the most part at least, these amino-acids rather than proteins *per se* that are absorbed and represent the ultimate alimentary contribution from the ingested proteins. The amino-acids are the fragmentary units in the form of which the albuminous intake is distributed throughout the body. From such fragments every individual tissue can select the con-

structive "building stones" which are specifically needed. Protein metabolism has thus become essentially a question of the behavior of amino-acids in the body. As I have expressed it elsewhere:

To-day we are concerned with the question whether this or that protein, whatever its biologic origin, will yield the characteristic desired, amino-acids, such as tyrosin and tryptophan, leucin and lysin, glycocoll and cystin, histidin and arginin. Our attention is fixed on the building-stones or units out of which the great protein structures are put together. Instead of referring to the proteins in terms of their physical properties or empirical composition—their content of carbon, hydrogen, oxygen, nitrogen or sulphur—at least so far as the problems of nutrition are involved, the time has arrived for estimating their behavior in the organism on the basis of the quota of each of about eighteen well-defined amino-acids which the individual representatives of this group of foodstuffs can yield. Most, if not all, of these amino-acids are essential for the construction of tissue and the regeneration of cellular losses. In proportion as any specific protein can furnish these constructive units it may satisfy the nutritive needs of the body. The efficiency of the individual protein in this respect must depend on the minimum of any indispensable amino-acid that it will yield; for it is now known that some of them cannot be synthesized anew by the animal organism. If, for example, a protein or mixture of proteins comparatively deficient in their yield of the sulphur-containing amino-acid cystin be furnished alone to supply the body's nitrogenous requirements, the production of new, cystin-yielding molecules of protein will be limited by the amount which is available in the diet. An excess need not be wasted, for it can be burned up like sugar or fat to provide energy; but new construction or growth is limited by the minimum of the essential unit.

The views just amplified have been substantiated by the more recent investigations in nutrition, particularly in the feeding of laboratory animals such as rats and mice. Thus, with an otherwise adequate diet the nitrogenous factors can be suitably supplied by proteins isolated from a considerable diversity of both animal and plant sources. The list includes such representatives as casein (milk), lactalbumin (milk), ovalbumin (hen's egg), ovovitellin (hen's egg), edestin (hemp-seed), globulin (squash-seed), excelsin (Brazil-nut), glutelin (maize), globulin (cotton-seed), glutenin (wheat), glycinin (soy-bean), cannabin (hemp-seed), as well as the total proteins present in various animal and plant tissues such as meat (muscle tissue), liver, kidney, brain, peanut, soy-bean, cotton-seed, etc. In contrast with the growth of white rats, for example, to adult size on mixtures of isolated food substances containing any one of the above as the chief source of protein in the diet is the failure to grow on foods containing other proteins which have a recognized deficiency in their amino-acid make-up, *i.e.*, "incomplete" proteins.

In every-day life neither man nor animals ordinarily eat a single type of protein or even proteins from a single source. The intake consists, rather, of a mixture of proteins rarely, if ever, including only such as are entirely deficient in their amino-acid make-up from the physiological standpoint just defined. Nevertheless there may be a *relative* deficiency of some essential nutrient unit or "building stone" in comparison with the amount of other essentials. Building progress—tissue construction—may then be retarded by the lack of proportionate quantities of all the needed parts that cannot be synthesized directly by the body.

An apparent exception to the demonstrated need of supplying all nitrogenous essentials more or less ready-made to the animal organism has been recorded in certain ruminants. Sheep have been observed to gain many pounds over considerable periods of time on a diet of starch, denitrogenized straw, inorganic salts and urea, an exceedingly simple nitrogenous compound that readily disintegrates to form ammonia and carbon dioxid. A consideration of the peculiar anatomical arrangement of the alimentary tract of these animals serves to explain the possibility of such an outcome. In the first stomach of the ruminants, the rumen or paunch, opportunity is afforded for micro-organisms to thrive in the warm reservoir where the food mixtures are temporarily incubated, so to speak. Bacteria can and do grow luxuriantly there. Subsequently when the products of microbial activity including an enormous increment of bacterial bodies are moved along to the true, acid-secreting stomach, the bacteria, rich in newly synthesized protein-containing protoplasm, die and liberate the bacterial protein for use by the organism of the host. This is a unique instance of apparent protein synthesis by a higher animal, explicable however on the basis of the symbiotic action of bacteria. The same result could not be expected in man, because his food passes directly into a chamber, the stomach, provided with bactericidal facilities in the acid gastric juice.

Even when the dietary food proteins are selected with a view to furnishing an adequate supply of all amino-acids known to be requisite, the nutritive processes of the body may exhibit defects not of supply but of utilization. A fire box may be equipped with a certain type of grate to burn coal of various sizes. If the grate is changed smaller sizes of fuel like pea coal may escape combustion by falling into the ashpit. So it happens that under as yet obscure conditions certain amino-acids fail to be completely

consumed or utilized in the metabolism. Consequently they are eliminated more or less unchanged with the waste products. Cystinuria and alkaptonuria represent illustrative instances.

There are other cases in which a presumably adequate intake fails to unfold its entire nutritive possibilities because some defect in the organism interferes with complete conversion of some ingredient. There are times when fats may fail of digestion and absorption. They then make their way through the entire length of the digestive tract, finding a way out with the stools. The disturbance or difficulty is one of digestion or alimentation. However, the fats may be digested, absorbed, and transported only to meet with inadequate chemical destruction in the usual reactions that liberate energy. Products of incomplete combustion arise, just as they do in the coal fire or gas engine. There may arise aceton, diacetic acid or betaoxybutyric acid, substances that are physiologically offensive and objectionable, that may induce an "acidosis," and that are speedily eliminated as well as possible.

Again, who is not familiar with the common condition known as diabetes in which sugar is not properly metabolized or stored in the body? There are in this country alone more than half a million diabetics, persons who fail to burn up one of the most common of food fuels. Striking statistics gathered by Doctor Joslin, of Boston, a conscientious student of diabetes, show an undeniable association of obesity and diabetes. It appears that persons above the age of fifty rarely acquire the disease, *i.e.*, the inability to burn certain kinds of food fuel well, if their weight is not above normal. Joslin writes:

> Diabetes is largely a penalty of obesity, and the greater the obesity, the more likely is Nature to enforce it. The sooner this is realized by physicians and the laity, the sooner will the advancing frequency of diabetes be checked. The penalty of taking too much alcohol is well known, and a drunkard is looked on with pity or contempt. Rarely persons who become fat deserve pity because of a real tendency to put on weight despite moderate eating, but usually most should be placed in somewhat the same category as the alcoholic. In the next generation one may be almost ashamed to have diabetes. It is all nonsense to use polite terms for being "just fat." It is generally prudent and always far more effective to say to the patient: "You are too fat," than cautiously to remark: "You are a trifle obese." Fat diathesis! Granted there is one person in a thousand who has some inherent peculiarity of the metabolism which has led to obesity, there are 999 for whom being fat implies too much food or too little exercise, or both combined.

Successful nutrition therefore not only demands the nutrient units properly digested and absorbed but also entails an organism in functioning condition to dispose of them. A water-power plant may become impaired not only when the supply reservoir runs low but also when its turbines or energy-converters are defective. But proteins and fats and sugars and their immediate chemical relatives are not the only indispensable factors in a successful diet. Present day physiology—again largely a product of the work of American investigators—has demonstrated the dominant importance of certain inorganic factors—of calcium phosphorus, chlorin, etc., and has given striking evidence of the rôle played by the so-called vitamines. The spark plug and lubricants help to make effective the energy stored in the gasoline supply of a heat engine. In nutrition likewise there are "accessories" without which the animal mechanism fails to run smoothly. The story of their importance may already be found portrayed with almost dramatic effect in the popular literature of the day.

It is instructive to follow the reaction of the public and the professions dealing with nutrition to each progressive step in the understanding of the nutritive functions. When the extent to which digestion occurs in the alimentary tract began to be disclosed by adequate experiments the predigestion of foods was promptly advocated, particularly for the sick and the young supposedly equipped with only feeble digestive apparatus. Meat and wheat and milk were prepared in a diversity of predigested forms by the physician, by the layman acting on his advice, and by the manufacturer.

To-day few remember the multiplicity of unpalatable products that were advertised and advocated a generation ago. In those days one might have spoken of foods "predigested to absorb" as nowadays one is reminded of foods "cooked ready to serve." No one seems to have asked whether the human alimentary tract was often so enfeebled as to require digestive help, or whether the exercise of the digestive function were not beneficial rather than baneful. Disuse of some organs leads to atrophy. An unexercised muscle becomes flabby. With the waning prominence of predigested foods, "isolated" foods, and notably protein food products waxed in popularity. The protein of pot cheese was sold at liberal profits, as a dietary supplement, mostly to the highly educated classes who are sometimes also highly credulous. At

present we are threatened with an avalanche of vitamine preparations. Somehow the drug store always manages to compete with the butcher shop and grocery, even in the domain of dietetics.

Students of nutrition are sometimes asked how it happens that nations have been so successfully nourished in the past despite the lack of knowledge of what are now regarded as fundamentals of nutrition. A partial answer has been formulated by Professor Hopkins:

> In many departments of human knowledge the teaching and guidance of science are accepted as final because in these departments the knowledge arose in the first instance from scientific studies and from these alone. Progress in such categories depends entirely upon controlled and recorded observation or upon experiment, and these are the methods of science. It is otherwise, one might be tempted to say, in regions where mankind can claim abundant and accumulated empirical experience. In connection with his own nutrition man's experience has been—needless to say—coterminous with his whole existence. Science may explain that experience, but is unlikely, it might seem, to improve upon experience as a guide. It may supply theory, but where experience has been so great and so continuous it seems unlikely that it could do much to guide practice. This consideration, consciously or subconsciously, accounts, I think, for a widespread feeling that the teachings of science about our food supply are of academic interest only.

We may hasten to add, however, that when peoples are forced to depart from the traditional practices that experience has shown to be safe, danger may arise. This is what happened in such unfortunate ways during the war. It is what may happen anywhere whenever persons depart from established and well tested customs to enter novel paths. Thus the substitution of polished rice for the unmilled variety led to nutritive disaster, often told in the story of beriberi. Pellagra has a related history. Rickets has a background of defective diet. Scurvy, too, attends the neglect of conventional modes of feeding. There is, then, room for a science of nutrition even in the domain of practical dietetics. Not all nations bungled their food problems during the war. How our British allies feel has lately been expressed by Professor Halliburton:

> Lord Rosebery, in a sentence that has stuck in our memories, said some years ago that "we generally muddle through somehow," but in connection with food there has been in this country a minimum of muddle, rationing has gone smoothly, there has been but little hardship, and we are through. How far physiology has been instrumental in helping to bring about this happy result I may safely leave to the judgment of others.

INTERNAL COMBUSTION ENGINES IN MARINE SERVICE.*

BY

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Part I.

PRESENT STANDARD OF MOTORSHIP AND TURBINE STEAMSHIP COMPARED.

At no time in marine history has there been so great a variety of ship-propelling machinery as at present, and consequently never has it been so difficult to forecast the future, or to formulate a policy of construction. Without some generally accepted policy, the machinery builder hesitates to face the risks of heavy investments for development and production of any one type of equipment that may not be acceptable to shipping interests in the near future, and shipping interests are reluctant to adopt any one type that may soon become obsolete. At this time of greatest engineering evolution, the general stagnation of business has forced hundreds of ships out of service, and practically stopped all demand for new construction. This condition, while very serious in most ways, will probably in the end prove to be a good thing, as it not only gives an opportunity for study, discussion, and appraisal of the situation, but really compels such a procedure.

If proper use is made of the opportunity to analyze each of the new types of ship propulsion proposed, and to arrive at some conclusions that can be generally accepted at least as to the relative position and value of each type, then we may be able to evolve a sound program. Such a program will undoubtedly involve the re-powering of some existing idle ships where the machinery is found to be already obsolete, and thus will provide immediate work for maintaining our shipyards and machine shops, which can then continue with new construction on the same program. Unless something of this sort is done, it is difficult to see how American

* Presented at the Stated Meeting of the Institute held Wednesday, April 20, 1921.

ships can compete with foreign ones, and our hopes for a stabilized American merchant marine can hardly be realized.

Those nations that regard their merchant marine as essential to their existence, will be most certain to immediately adopt and put into service any new propulsion plan that promises economies of ship operation. Such action will force the ships of the others that lag behind, into a losing position by making their older types of machinery obsolete in comparison with the new type adopted by the leaders. This taking of leadership by earliest adoption of newer and more economical propulsion has its risks also, risks of impaired life, less reliability, greater repairs, doubtful manœuvering ability and such matters, but these are the ordinary risks of all development and progress, and are largely matters of engineering, which, if good, reduces such risks to a minimum.

The relative economy of operation of one type of machinery installation compared with another is a matter of comparative operating costs and earnings, and each of these is the aggregate of a large number of items, some of which have high and others low values, for every different class of equipment. They also vary with the prices of consumable materials, including fuel, with wage scales, with freight rates, and by no means least, the amount of use to which the plant is put, measured by its average yearly load compared with the installed capacity. To arrive at any proper appraisal of value for one type of equipment, these items must all be known separately and added together, or estimates sufficiently good for appraisal purposes may be based on general averages for groups of items, when there is enough experience to make the average worthy of respect.

A great many estimates of this sort have been made and practically every time a proposal is offered for new ship machinery, this operation is repeated with sometimes more and sometimes less care, or accuracy, and open-mindedness. Many papers on the subject have been published. As a result it is generally understood by those most concerned, that there is no one best machinery installation for ships for all sizes, speeds, routes, periods of time and prices of commodities, and there probably never will be. That which is best for one condition may well be worst for another. The situation here may well be summarized by saying that relative economy depends more or less equally on four classes of factors, any one of which may control. These factors are:

a. Use factor;
b. Price factor (consumable supplies and wages);
c. Performance factor;
d. Investment factor.

High use factors favor, or rather are necessary for heavy investment charges as controlling the yearly returns or income for a given investment. High price factors favor equipment working with low consumption of consumable supplies and low labor requirements for both operation and repair. High performance factors, representing large consumption of consumable supplies, mainly fuel, are always unfavorable, and are permissible only when other items are low because of it, as, for example, the investment factor. High investment factors representing large first costs are justifiable in proportion as other factors are so reduced by this high investment as to yield larger net percentage returns on high, than on low investments.

That analysis of operating economy will be most satisfactory which first eliminates all non-competitive equipment, and then for each of the remaining types of main power generating machinery, of auxiliary machinery and of propeller drives, determines the values of its performance and investment factors, and assigns to each one its own appropriate use factor limits, for fair ranges of the price factors. This analysis will have the effect of dividing all sea-borne traffic into classes or zones, according to the use factors representative of each in terms of length of voyage or of cargo ton-miles per year for example, in each one of which a given type of ship would be most economical with given prices, and which would change with prices. In proportion as the economic zones have the least overlap, so will the different kinds of ships be least competitive, and the proper place for each in world cargo-carrying be determined, as the basis of a program of construction and reconstruction.

This is not an easy task, and its complete and accurate execution may hardly be expected, but in proportion as it is approached and re-checked periodically, so will order and certainty emerge from disorder and uncertainty. Fair approximations for specified cases of comparison are not difficult and a start can be made this way. This is undertaken in what follows and it is hoped that some useful conclusions can be based on the method developed.

If there were no diversity of machinery, each with different

factors of investment and performance, the problem would be purely one of size of ship, price of fuel and other supplies, wages and number of crew, and this was the situation before the steam turbine and the internal combustion engine appeared. At that time the more expensive steamship had proved itself to be more economical than the cheaper sailing vessel, mainly through greater use factors and in spite of additional operating expenses for consumable supplies. Also at this time, all steamships were coal burners with reciprocating steam engines and differed in performance factors according to the efficiency of their reciprocating steam engines and auxiliaries, the one having higher efficiency always costing more to install and usually also to maintain. Here again, experience demonstrated that the higher investment costs for the more efficient coal-burning steamer were justified and profitable whenever the use factors were high, and not so when they were low, so the small tramp steamer of uncertain cargo-carrying capacity per year was properly propelled by the cheapest and least efficient machinery.

The old stable situation, where the problems were mainly non-engineering in character, and competition depended on crew wages and size with a given size of ship, on shipping management, and possibly on government coöperation, has for the moment entirely disappeared, and while some of the old problems remain, new ones have come forward and are to-day dominant.

These new ones are the result of, (*a*) the use of oil as fuel in competition with coal; (*b*) the steam turbine; and (*c*) the internal combustion engine. The first reduces fire-room crew, increases cargo capacity, decreases time, frequence and expense for loading fuel, and it has resulted in the establishment of fuel oil storage stations throughout the world, which have contributed to the introduction of the heavy oil internal combustion engine. Another effect of no small consequence has been the stimulation of new oil-well developments, in coöperation with the parallel demand of the automotive industries for greatly increased amounts of petroleum products, a true coöperation, because those parts of the crude oil that the latter cannot use as rejected residue, the former can use effectively.

One of the lessons taught by the substitution of fuel oil for coal in steamers, is that a higher specific price per million B.T.U. may be fully justified by reduced costs in other directions, and that the

more expensive fuel to buy, may be the cheapest to burn. This lesson is again repeated by the internal combustion engine in increasing degree, as is also the older lesson that increased investment costs may be more profitable than lesser ones.

The steam turbine, at first multi-staged to excess and direct coupled, was not very successful, many installations gave operating trouble and few showed a net saving in fuel, weight or cost. If it had not been for the inherent fundamental soundness of the turbine idea, inspiring persistent efforts to overcome mechanical troubles, and to reduce cost to realize these possibilities, it might well have been abandoned as an unlucky experiment. Faith in fundamental soundness of principle of the turbine kept it alive, and constant study of mechanical and operating faults resulted in their steady reduction or elimination, at first on land for central station electric generation service. However, for marine use there still remained the inherent high speed of turbine and low speed of propeller, which required more study of failures and development of corrections. As a result of all this the high speed marine steam turbine of to-day is a successful machine and has come into general use with single or double reduction gear drive of the propeller shaft. This equipment has a lower steam consumption and higher thermal efficiency than the reciprocating engine it has displaced, and it costs less to install, thus having more favorable use, performance, and investment factors.

In the meantime the Diesel oil engine was going through a more or less similar history. Its inherently higher thermal efficiency, two to three times that of the steam turbine plant, attracted to it the same sort of attention as did the turbine with its promise of low weight, cost and good steam consumption. Diesel engine development proceeded in spite of handicaps of very much higher first cost, greater weight and doubtful reliability at first, because of efficiency prospects. As was the case with the turbine, its success was first established on land, and also as with the turbine, the early marine installations, were mostly failures, but again as with the turbine, faith in the soundness of fundamental possibilities has served to overcome the discouragements, and to-day it may be said that mechanical defects have been remedied by good design and workmanship, so that reliability is established quite equal to that of the turbine installation. While there are still a great many more different models of marine Diesel engines than

of turbines, some as good as the best and others not, some new and others old, some American and others European, and an even greater variety of auxiliaries, it is safe to say that the standard motorship installation of the day is the four-cycle, multi-cylinder (six or more), single-acting, air-injection engine with crosshead, direct coupled in pairs to twin screw propeller shafts. The corresponding standard for auxiliaries is a combination of small Diesel electric generating sets, with all engine room and deck equipment electrically operated, and with air compressors and compressed air storage tanks for manœuvering. There are many such ships in operation and some have been in service long enough to justify their acceptance as standards, especially as so much new construction follows the same lines with only natural improvements in details.

The corresponding standard of the steam turbine class is the geared turbine with single propeller shaft, served by oil-fired Scotch boilers with superheaters and with steam auxiliaries, both engine room and deck.

These two modern standards of new type cargo ship machinery installation are in competition with each other, and can be taken as the basis of any study of the several diversity factors affecting economy estimates. Such a study must be directed first, toward the fixing of the economic zone of operation for each type in terms of the use factors with given prices of supplies. After this is done, the possible modifications of both turbine and motorship standards, can then be studied as to their effect on economy or economic operating zone.

Such studies will involve in the case of the turbine, the effect of changing the propeller connection from gear to electric transmission from the turbine, and of changing auxiliaries from steam to electric, the electricity being generated by small turbogenerator sets, by Diesel oil engine generating sets, or taken from the main generators. In the case of the Diesel oil engine, it will involve an estimate of the effect of changing the engine from four-cycle to two-cycle, from single to double acting, from air injection to solid injection, from Diesel method to others not Diesel, of better utilization of air charges in the cylinder with higher mean pressures, of different stroke-bore ratios and rotative speeds, of different numbers of cylinders per engine, of trunk piston against crosshead. As to propeller connection the study must include the

effect of single screw direct coupled against twin, of larger numbers of small cylinder high-speed main engines, geared to a single propeller shaft, or for electric drive, each engine driving electric generators and with the motor on the propeller shaft, eliminating the auxiliary generating engines, and also the manœuvering air compressor with its storage tanks.

By effect of each change is meant the change in weight and space involved in relation to cargo-capacity, in first cost or investment, in disbursements for fuel and other consumable supplies, in labor for operation and repairs, and other items, with estimates of relative life and reliability. In every case the other diversity factors must be brought in to fix the economic position.

The first detailed step in all this is to compare the standard geared turbine ship with the corresponding standard motorship. For this it is necessary to assume certain typical conditions and the first of these is size, power and speed of ship, and to define each equipment by a list of its principal items.

The ships assumed are taken as 10,000 tons dead-weight, speed 12 knots, 288 nautical miles per day, each equipped with 3500 S.H.P., and of equal propeller efficiency for the twin-screw motorship and the single screw turbine steamer, the justification for which has been much discussed and pretty well established. Such a ship would be about 425 feet long, 55 feet beam and draft of 27 feet loaded.

These two machinery installations include the items listed in Table I and Table II, from which it appears that the machinery of the turbine ship weighs 632 long tons, and that of the motorship 1020 tons, a difference in favor of the former 388 tons, of which difference 37 tons is due to the difference in shafting and propellers for twin as compared with single screw, and 5 tons to electric compared with steam deck gear, leaving 346 tons, due to the machinery proper. There are also some items of hull difference, but taking into consideration additional fresh water and fuel tank capacity to equalize the steaming radius of the steamer with that of the motorship, which latter can rely on its double bottom bunkers alone, these hull-weight differences can be regarded as equalized in any general comparison.

The tables also show that on the basis of costs, which are estimated at this time of unstable prices in a falling market at about 20 per cent. less than a year ago, and, therefore, somewhat doubt-

ful though relatively fair, that the Diesel machinery will cost \$581,000, the turbine machinery \$275,000, a difference of \$306,000 against the motorship. Of the difference \$14,000 is due to twin propellers and shaft over single, \$40,000, to electric over steam auxiliaries, leaving \$252,000 difference due to propelling machinery proper.

These two ships complete are estimated to cost \$1,556,000 for the motorship, or \$156 per D.W. ton, and \$1,250,000 for the

TABLE I.

Equipment List for Installation of Geared Turbine, 185 lbs. Steam Pressure, 100° Superheat, 28.5" Vacuum, Single Screw, 3500 S. H. P. at 90 R.P.M.

Group	Equipment Item	Weight. Long ton	Cost. Dollars
A	One 3500 S. H. P. geared turbine, with oil system, cooler and lubricating pumps	88.00	\$88,000
B	Three Scotch boilers, full, complete with superheaters and stack, fuel oil burner sets and transfer pump, boiler feed pumps and feed water heater	320.00	80,000
C	Fresh water systems, tank, evaporator and distiller	6.00	1,500
D	Engine room power auxiliaries; main and auxiliary condenser, with circulating air and vacuum pumps	30.00	24,000
E	Engine room ship auxiliaries; ballast, sanitary, bilge and fire pumps	5.00	2,000
F	Two steam auxiliary generating sets 15 K. W. each with generators and switch boards	5.00	3,600
G	Fixed engine and boiler room equipment; piping, platforms, spares and stores	35.00	32,000
H	Deck auxiliaries; ten steam winches, windlass and stearing engine	55.00	20,000
I	Power transmission; propeller, shafting and bearing and stern tube	88.00	24,000
	Total	632.00	\$275,000
	Total per S. H. P.	.180 tons	\$79.00

geared turbine steamer or \$125 per D.W. ton, the difference of \$306,000, or \$31 per D. W. ton being against the motorship.

The cargo capacities of these ships will not be equal because of the differences in machinery weights and in consumable supplies such as stores, water and fuel oil, mainly the latter. To estimate these items it is necessary to establish consumption rates per day at sea and in port, and to apply these to different lengths of voyages and port periods over a year to get yearly cargo-capacity, assuming the ship to be full every voyage, from which by applying freight rates the yearly gross earnings of the ship can be estimated.

Both ships will burn the same fuel oil and as a fair average of the world's supply, bunker oil of 14°–16° Baume will be taken. It has been the custom to operate Diesel engines on a higher grade oil of suitable viscosity to be handled cold by the engine metering pumps, to give a properly fine spray when injected. Recent tests of oil conditioning equipment have proved that the viscosity

TABLE II.

Equipment List for Twin Screw Diesel Engine (65 B. M. E. P.), 3500 S. H. P., 120 R.P.M. Installation.

Group	Equipment Item	Weight. Long ton	Cost. Dollars
A	Two 1750 B. H. P., six cylinder air injection Diesel engines with attached air compressors, thrust shaft and bearing, exhaust manifold silencer, spray air bottles, lubricating oil filters, coolers, platforms and spare parts per Lloyds	700.00	$390,000
B	Three 150 B. H. P.-100 K. W. auxiliary Diesel engine generating sets with air bottles, silencers, piping valves 220 volts D. C. generator and controls	66.00	48,000
C	One small emergency oil engine lighting set, 10 K. W.	1.00	1,000
D	One donkey boiler, 200 square feet, with feed pump and oil burner, for heating ship and fuel oil	8.00	1,000
E	One motor drive three stage auxiliary air compressor, 220 H. P.	10.00	15,000
F	Pumps for fresh water, fire and bilge, ballast, fuel oil transfer, lubricating oil, bilge, fire and bilge, fresh water and sanitary and steam emergency air compressor	20.00	15,000
G	Fixed engine room equipment; additional piping, stack and tanks	30.00	13,000
H	Deck auxiliaries; ten electric winches, windlass and stearing gears	60.00	60,000
I	Power transmission; propellers, shafts, bearings and stern tubes	125.00	38,000
	Total	1020.00	$581,000
	Total per H. P.	.290 tons	$165.00

of oils that cannot be used cold can be changed by heating to the same values as the old standard Diesel fuel oils, and it is no longer necessary to select an oil for these engines when this fuel oil conditioning equipment is installed. This confirms the experience of the Navy as to equalization of oils by heating to equal viscosity when used in mechanical spray burners for steam boilers. This apparatus involves a steam heating system served by the donkey boiler and a centrifugal separator to remove all solids and water

after viscosity adjustment by heating, and which centrifuge by the use of a reagent can also break down emulsions into clean oil and water.

This fuel oil will weigh 8 lbs. per gallon, 338 lbs. per 42 net gal. barrels, or 6.62 bbls. per long ton, approximately.

The fuel oil consumption of Diesel engines is very constant and differs but little in service from test floor values, any mal-adjustment producing smoke immediately calls attention to a faulty spray valve which is easily corrected. The value may be taken as .46 lb. per S.H.P. hr. for all purposes at sea, which is about 10 per cent. above test value. This is equivalent to $3500 \times .46 = 1620$ lbs. per hour, 38,940 lbs. per day of 24 hours, 17.4 long tons, or 115 bbls.

In port the fuel consumption is much less, part being that for winch operation when handling cargo, and the rest that for pumps at all times, and ship lighting, both loads being carried by the auxiliary Diesel generating sets. For this service at variable load, the consumption is estimated at .6 ton per day for the twenty days in each port call. This makes the port consumption $20 \times .6 = 12$ tons, or 79 bbls. per port call.

The steam turbine ship fuel consumption at sea is based on the assumption that the turbine will have a sea water rate of 12 lbs. per S.H.P. on the average, about 20 per cent. above the test value, 2 lbs. per S.H.P. hr. for auxiliaries, making a total of 14 lbs. steam per hr. per S.H.P. for all purposes at sea, and 49,000 lbs. per hour total. The boiler evaporation is taken as 12 lbs. per lb. of oil, making allowance for normally imperfect adjustment of burners and air supply. This makes the fuel consumption for all purposes at sea, $\frac{49{,}000}{12} = 4092$ bbls. per hr. = 1.17 lbs. per hr. per S.H.P., which is equivalent to 98,208 lbs. per day of 24 hours, 44 long tons, or 293 lbs.

In port the steamer fuel consumption is estimated from ships in service as 30 bbls. per day for 20 days, or a total of 600 bbls., or 90 tons per port call, neglecting increases for winter steam heat, which will double the amount.

Comparing these consumptions the ratio of steamer fuel oil consumption to the motorship is, at sea, 2.5 times, and 7.5 times in port.

Fresh water estimates are based on 20 gallons per day per

man, or 3 tons per day for each ship for washing, drinking and cooking. Steamship make-up water is estimated at 1.5 per cent. of the boiler evaporation, or 10 tons per day at sea, to be stored in tanks, with an alternative of a lesser amount carried in tanks, and an increased fuel consumption to make fresh water by evaporation and distillation. It will be assumed that water can be obtained at any port and a one-way supply carried.

Stores for deck, engine and steward's department are estimated at one ton per day for each ship and as not always obtainable at every port, a round trip supply to be carried on leaving.

The aggregate weights of fuel, water and stores for a given voyage will depend on its length and so, therefore, will the cargo capacity, making allowance for machinery weight excesses.

No general conclusions as to relative economic scope of the

TABLE III.

Consumption Rates of Consumable Supplies (Long Tons).

Item	Per day at sea		Per day in port	
	Steamship	Motorship	Steamship	Motorship
Stores	1.00	1.00	1.00	1.00
Water	13.00	3.00	3.00	3.00
Fuel	44.00	17.40	90 tons per call—	12 tons per call

two typical ships can be based on a voyage length assumed, because the motorship is favored by long, and the steamer by short voyages, so that the problem becomes one of finding the voyage length that divides the economic zone of one ship from that of the other, and on a yearly basis of operating 350 days per year, allowing 15 days per year for docking and general overhaul.

For the purpose of such general comparison of types, it is necessary to reduce the number of variables to a minimum, and for graphical plotting to select a prime variable. This prime variable is here taken as the length of a single voyage in days, and in all cases the port stay is assumed to be the economical low limit of 20 days, which may possibly be too low, requiring as it does the handling of something less than 100 tons of cargo per day per winch, by whatever proportionate amount the total cargo is less than 10,000 tons in weight.

The calculation of consumable supplies is based on the rates

of Tables III, and the figures are tabulated in Table IV, for a complete round trip voyage. In this table the maximum length of voyage has been based on the double bottom bunker capacity of 1200 tons and the consumption of the motorship, and fixed at about 60 days, which the motorship can complete one way, without refuelling, and with about 10 per cent. reserve, filling bunkers at each end. To meet these conditions of voyage length, the steamer must have deep tanks of about 1700 tons additional fuel capacity. For voyages of half this length, or 30 days, both

TABLE IV.

Consumable Supplies: Tons per Return Voyage.

Days, Single Voyage		Stores		Water		Fuel		Total		Total Weight, 10% Reserve	
Sea	Lay	Out	In	Out	In	Out	In	Out	In	Out	In
STEAMSHIP											
5	20	50	25	125	125	310	310	485	460	531	506
10	20	60	30	190	190	530	530	780	750	855	825
20	20	80	40	320	320	970	970	1370	1330	1503	1463
30	20	100	50	450	450	1410	1410	1960	1910	2151	2101
40	20	120	60	580	580	1850	1850	2550	2490	2799	2739
50	20	140	70	710	710	2240	2240	3140	3070	3447	3377
60	20	160	80	840	840	2730	2730	3730	3650	4095	4015
MOTORSHIP											
5	20	50	25	75	75	99	99	224	199	244	219
10	20	60	30	90	90	186	186	336	306	367	337
20	20	80	40	120	120	360	360	560	520	612	572
30	20	100	50	150	150	534	534	784	734	857	807
40	20	120	60	180	180	708	708	1008	948	1103	1043
50	20	140	70	210	210	882	882	1232	1162	1348	1278
60	20	160	80	240	240	1056	1056	1450	1376	1594	1514

ships might carry oil for a return voyage, but the conditions are normally more favorable when the fuel is carried one way only, permitting an increase of cargo-capacity outbound equal to the fuel consumption one way. This is a matter of balancing relative values of this weight of fuel and of cargo.

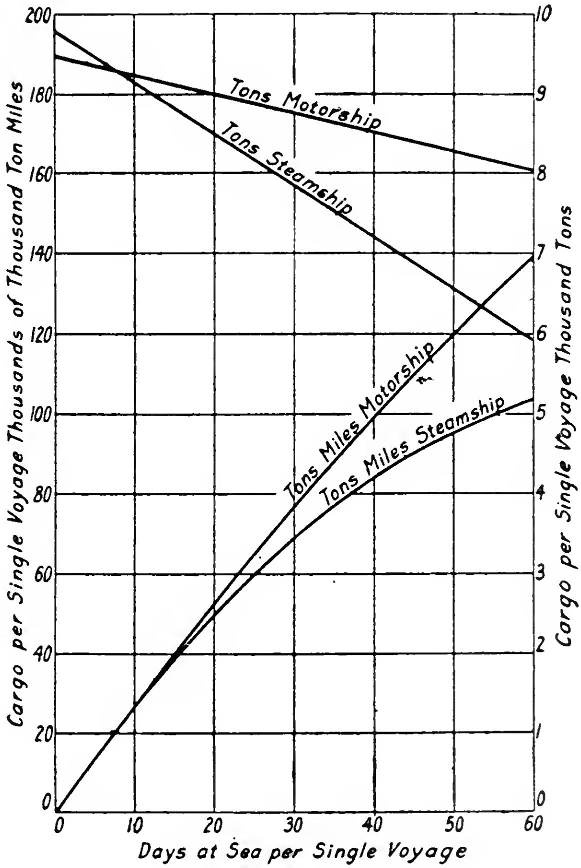
The cargo capacity determined by subtracting supplies from dead-weight is plotted in Fig. 1.

It will be noted that the steamship and motorship curves are not parallel but depart more widely as voyage length is greater, and in favor of the motorship.

To make this still more clear, the dead-weight distribution given in Table V is plotted in Fig. 2, making an allowance of 388 tons excess machinery weight of the motorship over the steamer.

Combining the items of cargo-capacity per single voyage with

FIG. 1.



Cargo-Capacity per Single Voyage Tons and Ton-Miles.

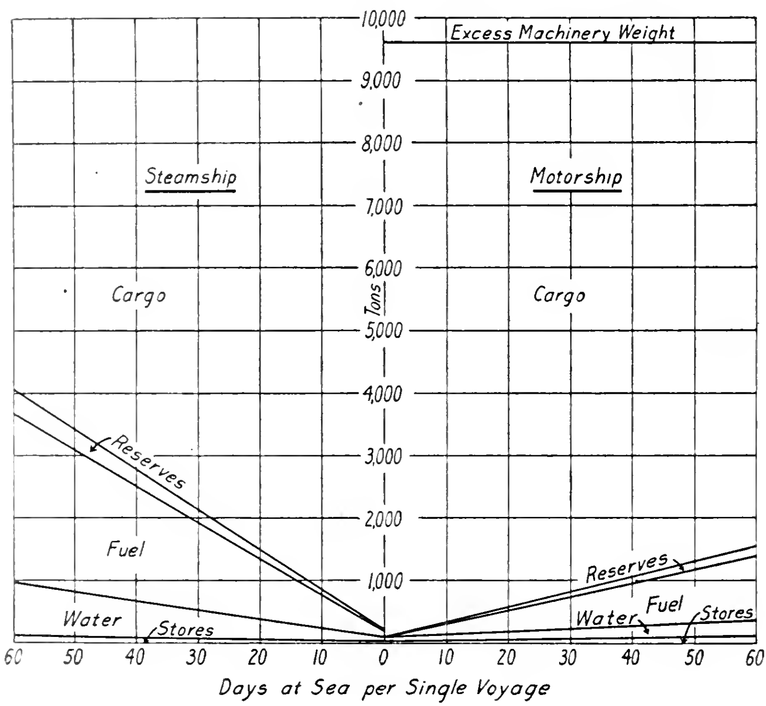
miles per voyage, voyages per year, and freight rates, the yearly gross earnings are found as reported in Table VI, for freight rates of \$1, \$2, and \$3 per 1000 ton-miles. The corresponding returns for any other freight rate can be obtained by scaling.

This table of gross freight earnings brings out the interesting

fact that there is a maximum for each type of ship, for the steamer at less than 40 days length of voyage, and for the motorship at over 60 days length. The curves of gross earnings in Fig. 3 show this more clearly.

Mainly because of fuel economy, but also because of no fresh water make-up storage, the motorship freight earnings are con-

FIG. 2.



Dead-Weight Distribution in Tons.

sistently greater than the steamer for any freight rate, the actual difference being greater for longer voyages at any one freight rate and, of course, doubly so at the higher freight rates.

Disbursements per year for ship operation include two sets of items, one that is actually or practically independent of length of voyage, port stay or horsepower hours of power generated per year, and the other that varies with the factors entering into the latter item. These disbursements must be estimated and the total

TABLE V.

Dead-Weight Distribution (Long Tons) (Average Single Voyage)

STEAMSHIP

Sea days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total + Reserve	CARGO 10,000 − (total + reserve)
5	38	125	163	310	473	520	9480
10	45	190	235	530	765	842	9158
20	60	320	380	970	1350	1485	8515
30	75	450	525	1410	1935	2129	7871
40	90	580	670	1850	2520	2770	7230
50	105	710	815	2290	3105	3416	6584
60	120	840	960	2730	3690	4059	5941

MOTORSHIP

Sea days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total + Reserve	CARGO 9612 − (total + reserve)
5	38	75	113	99	212	233	9379
10	45	90	135	186	311	342	9270
20	60	120	180	360	540	594	9018
30	75	150	225	534	759	835	8777
40	90	180	270	708	978	1076	8536
50	105	210	315	882	1197	1317	8295
60	120	240	360	1056	1416	1557	8055

TABLE VI.

Cargo (D. W.) Capacity and Yearly Gross Freight Earnings.

STEAMSHIP

Days per single voyage		D. W. per single voyage ave.		Distance, miles	Ton-miles cargo per single voyage	Single voyage per year of 350 days	Thousand ton-miles per year	Gross earnings at freight rates per 1000 ton-miles of		
Sea	Lay	Supply	Cargo					$1.00	$2.00	$3.00
5	20	520	9480	1,440	13,650	14.00	191,000	$191,000	$383,000	$573,000
10	20	842	9158	2,880	26,390	11.65	307,200	307,200	614,400	921,500
20	20	1485	8515	5,760	49,050	8.75	429,500	429,500	859,000	1,266,500
30	20	2129	7871	8,640	68,000	7.00	475,500	475,500	951,000	1,426,500
40	20	2770	7230	11,520	83,300	5.84	485,500	485,500	971,000	1,456,500
50	20	3416	6584	14,400	94,800	5.00	474,000	474,000	948,000	1,422,000
60	20	4050	5941	17,280	102,600	4.38	449,000	449,000	898,000	1,347,000

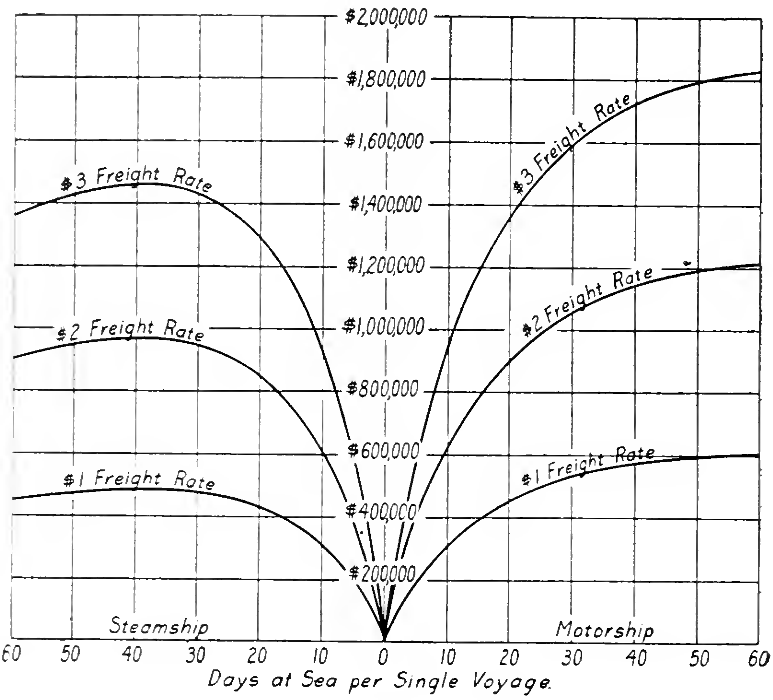
MOTORSHIP

Sea	Lay	Supply	Cargo	Distance, miles	Ton-miles cargo per single voyage	Single voyage per year of 350 days	Thousand ton-miles per year	$1.00	$2.00	$3.00
5	20	233	9379	1,440	13,500	14.00	189,000	$189,000	$398,000	$567,000
10	20	342	9270	2,880	26,700	11.65	311,000	311,000	622,000	933,000
20	20	594	9018	5,760	52,000	8.75	455,000	455,000	910,000	1,365,000
30	20	835	8777	8,640	75,800	7.00	530,000	530,000	1,060,000	1,690,000
40	20	1076	8536	11,520	98,400	5.84	574,000	574,000	1,148,000	1,722,000
50	20	1317	8295	14,400	119,300	5.00	596,500	596,500	1,193,000	1,789,500
60	20	1557	8055	17,280	139,100	4.38	609,500	609,500	1,219,000	1,828,500

subtracted from the gross freight earnings to get yearly returns on the capital invested.

The returns so found may be distributed into various sinking fund reserve accounts, such as interest, depreciation, obsolescence, bond retirement, or part may be actually disbursed as profits or dividends. To establish the relative economic zones for the

FIG. 3.



Gross Freight Earnings per Year in Dollars.

two types of ships, this distribution of yearly capital returns need not be made, it is quite sufficient to determine the amounts, and this can be done without obscuring the issue with theories of accounting.

It has already been shown that there is a difference in gross freight returns for the two types of ships, and the same will be true as to disbursements for operating expenses, but in a somewhat different way. When the curves for these latter items are devel-

oped and compared with the former, the profitable zone of each type of vessel will be apparent.

Operating expense disbursements include items for maintenance, crew wages and subsistence, loss and damage, stores and insurance, as annual items, actually or substantially independent of the length of voyage. Port expenses and fuel are the only items large enough and sufficiently variable with the service or the power generated, to warrant independent calculation in terms of length of voyage. Cargo handling is omitted as it is more of a terminal or freight transfer charge than one of ocean transportation.

Maintenance data available, while not yet conclusive, do never the less point to substantial equality between the geared turbine machinery and the Diesel engine, each of good design. In the former case, the major single item is for the boilers. At pre-war wages, labor efficiency and prices of material, the amount was about $8000 per year, and a year ago about twice this, $15,000 per year. Adding to this an amount for maintenance of ship, ship fittings and deck gear, and two dry dockings at $5000 each, the total would have been about $40,000 per year, or $4 per D.W.T. per year. At the present time with wages and prices falling, an estimate for the future must be somewhat of a guess, but a reduction of 20 per cent. will be made as was done for ship's costs. This makes the total $32,000 per year for each ship.

Crew wages and subsistence have been very carefully determined for conditions of the near past on established complements, and pay scales, and these figures will be reduced by 10 per cent. for wages, and 20 per cent. for subsistence in anticipation of a reduction likely to come soon, in line with all prices and wages. While it is possible to operate the motorship with less men than the steamer, no advantage is taken of this and both ships are charged with the same expense. To save space, the details of the crews will be omitted, but the summary is as follows: The engine room force consists of 17 men, receiving $24,400 per year for wages, and costing $7500 for subsistence, a total of $31,900 per year. Deck and stewards complements add 26 men to each ship with $30,000 wages and $11,400 subsistence or $41,400 together. This makes the total $73,300 per year for wages and subsistence for each ship.

Loss and damage is almost a pure guess, and for it a total of $10 per day for each ship is assumed, or $3650 per year.

Stores, exclusive of subsistence, and amounting to one ton per day, are priced at $60 per ton average, making the yearly charge $21,900.

Water is worth so small a sum per ton and the total yearly amount is also so small as to make this item of expense negligible, and it is, therefore, omitted.

Insurance is taken at the flat rate of 5 per cent. on the ship

TABLE VII.

Fixed Annual Disbursements.

Item	Steamship	Motorship
Maintenance	$32,000	$32,000
Crew wage and subsistence	73,300	73,300
Loss and damage	3,650	3,650
Stores	21,900	21,900
Insurance................	62,500	77,800
Total................	$193,350	$208,650

YEARLY PORT CHARGES, BOTH SHIPS

Day per single voyage	Single voyages per year port calls	Yearly port charges, approximate
5	14.00	$112,000
10	11.65	93,200
20	8.75	70,000
30	7.00	56,000
40	5.84	46,720
50	5.00	40,000
60	4.38	33,040

cost because this seems to be the custom, and in spite of the fact that it seems to be a high figure. This is equivalent to an annual charge of $77,800 per year against the motorship and $62,500 per year for the steamship.

These annual items together make up the totals for the fixed annual disbursements of the two ships as in Table VII.

To these totals are to be added amounts for port expenses, which vary with the days in port, and for fuel expense, which varies with days at sea and in port.

TABLE VIII.
Annual Fuel Expense.

Days per single voyage	Single voyages per year	Fuel tons per single voyage	Fuel tons per year	Fuel bbls. per year	Fuel expense per year at dollars per bbl. of 1	2	3	4	5
STEAMSHIP									
5	14.00	310	4,340	28,730	$28,700	$ 57,500	$ 86,200	$114,900	$143,700
10	11.65	530	6,175	40,875	40,900	81,750	123,000	163,500	204,400
20	8.75	970	8,488	56,185	56,200	112,400	168,600	224,700	280,900
30	7.00	1410	9,870	65,340	65,300	130,700	196,000	261,400	326,700
40	5.84	1850	10,800	71,520	71,500	143,000	214,600	286,100	357,600
50	5.00	2290	11,450	75,800	75,800	151,600	227,400	303,200	379,000
60	4.38	2730	11,957	79,160	79,200	158,300	237,500	316,600	395,800
MOTORSHIP									
5	14.00	99	1386	9,175	$ 9,200	$18,350	$27,500	$36,700	$ 45,900
10	11.65	186	2167	14,345	14,300	28,700	43,000	57,400	71,700
20	8.75	360	3150	20,853	20,850	41,700	62,600	83,400	104,300
30	7.00	534	3738	24,746	24,700	49,500	74,200	99,000	123,700
40	5.84	708	4135	27,374	27,400	54,700	82,100	109,500	136,900
50	5.00	882	4410	29,194	29,200	58,400	87,600	116,800	146,000
60	4.38	1056	4625	30,618	30,600	61,200	91,900	122,500	153,100

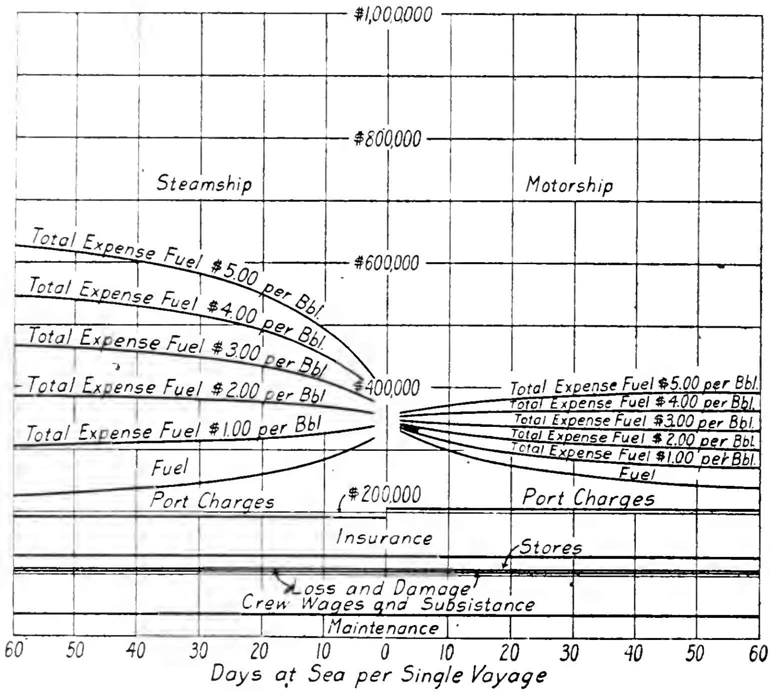
TABLE IX.
Total Annual Expense.

Days per single voyage	Total expense with fuel in dollars per bbl. at $1.00	$2.00	$3.00	$4.00	$5.00
STEAMSHIP					
5	$334,000	$363,000	$391,500	$420,000	$449,000
10	327,500	368,000	409,000	450,000	491,000
20	319,500	376,000	432,000	488,000	544,000
30	315,000	380,000	445,000	511,000	576,000
40	311,500	383,000	454,500	.526,000	598,000
50	309,000	385,000	461,000	536,000	612,000
60	307,000	387,000	466,000	545,000	624,000
MOTORSHIP					
5	$329,500	$339,000	$348,000	$357,500	$366,500
10	316,500	330,500	344,500	359,000	373,500
20	299,500	320,500	341,500	362,000	382,500
30	289,500	314,000	338,500	363,500	388,500
40	282,500	310,000	337,500	364,500	392,000
50	277,500	307,000	336,000	365,500	394,500
60	274,500	304,500	335,500	366,000	396,500

Port charges, exclusive of cargo handling, represent the cost of entering, leaving, and remaining in port in proper position to handle cargo, and this expense will be the same for both ships, so detailed itemization is not worth while. A round figure of $400 per day in port will be assumed, and as the stay in port is fixed at 20 days, this means a charge of $8000 per port call. The yearly port charge totals are given in Table VII.

Fuel expense can be determined from the consumption figures

FIG. 4.



Total Annual Expense.

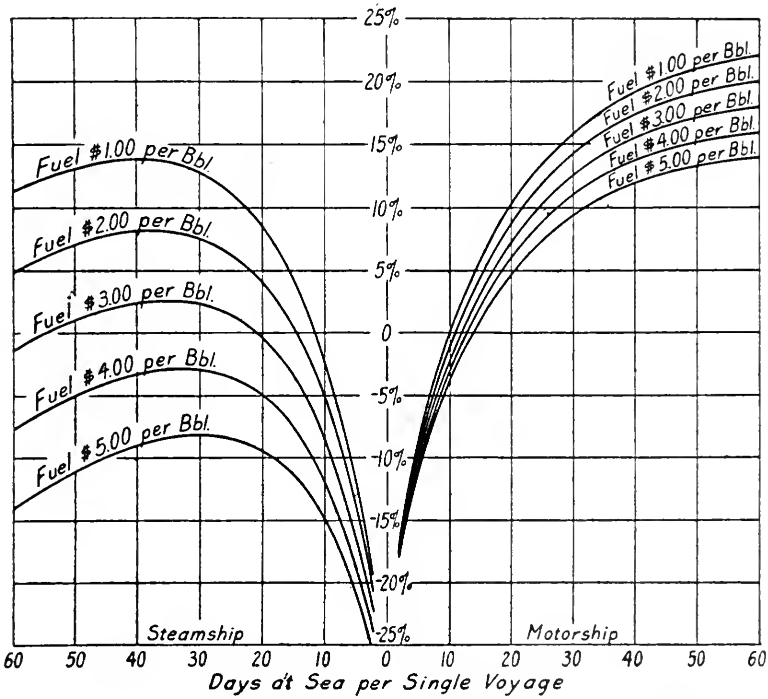
and days at sea or in port by applying a price. As price is a variable in the fixing of economic zones, no one value will be taken, but the total computed for a range from $1 to $5 per bbl. within which fuel oil prices for bunker grades will surely lie for a long time to come. This fuel expense calculation is assembled in Table VIII.

To the fuel expense per year, which increases regularly, with length of voyage, there is to be added the port expense per year, which decreases with length of voyage, the sum for low fuel prices

decreasing with length of voyage, becoming about constant for moderate fuel prices, and increasing with high fuel prices. The fixed annual expenses added to the above sum, give total yearly expense, per Table IX, and as plotted in the curves of Fig. 4.

These curves show clearly that exclusive of fuel, the yearly expense is slightly greater for the motorship, but including fuel, the situation is reversed, the total being always greater for the

FIG. 5.



Annual Return on Investment with Freight Rate at $1.00 per 1000 Ton-Miles.

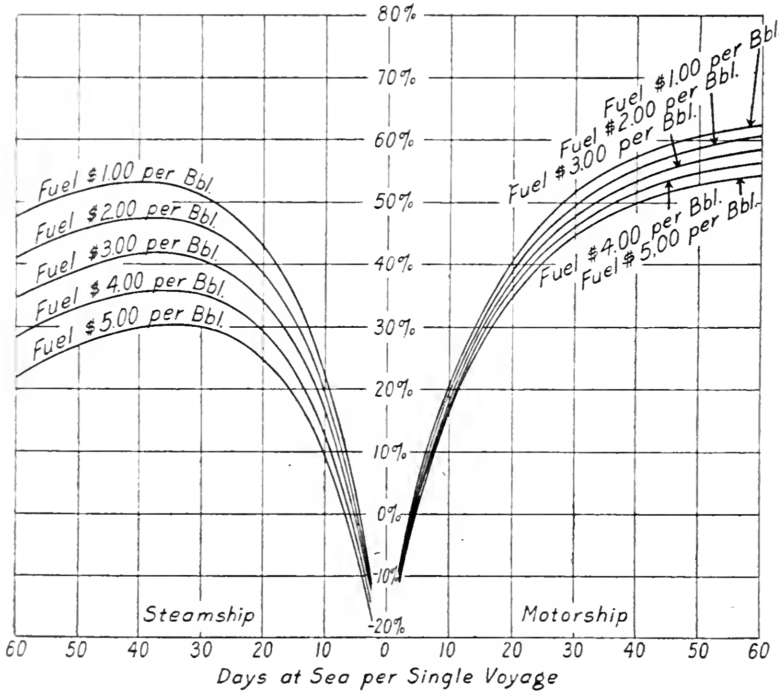
steamer for any voyage length, and the excess itself being greater as fuel prices rise.

Subtracting the annual expense of Table IX and Fig. 4, from the annual freight income of Table VI and Fig. 3, there is found the annual returns on the investment in dollars per year, and per cent. on the first cost of the ship per Table X, *A* for $1, *B* for $2 and *C* for $3 freight rates per 1000 ton-miles, each for fuel oil prices from $1 to $5 per bbl. These per cent. returns on the

investment are plotted in three curves, Figs. 5, 6 and 7, for the three freight rates.

It will be noted from the curves that in all cases the returns for the steamship reach a maximum and then fall, as length of voyage increases, while for the motorship no maximum is reached. The curves for the two ships are at first, *i.e.*, for short voyages,

FIG. 6.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

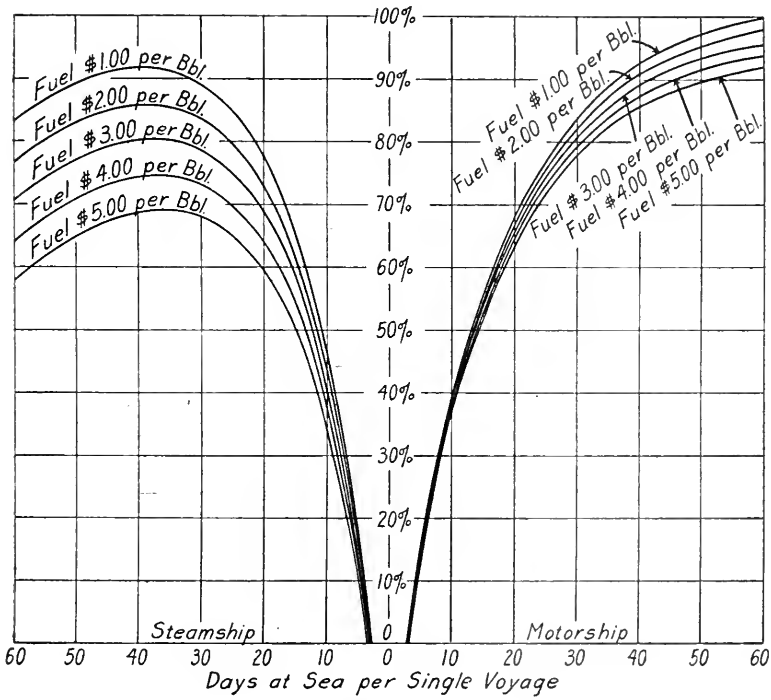
nearly straight lines and more or less parallel, a condition that indicates a competitive condition for short voyages. As voyage length increases, however, the curves of steamship returns flatten out, while those of the motorship continue to rise, indicating a non-competitive condition, or one of definitely clear superiority of the motorship. Just where the competitive condition ends, or for what lengths of voyage the two ships yield substantially equal returns, or below what voyage length the steamer is more profit-

able, or above which the motorship returns are better, depends on freight rates and on fuel oil prices.

That there are clearly independent as well as clearly competitive zones becomes more clear as these investment returns are compared directly, as is done in Table XI, and curves of Figs. 8, 9 and 10, for $1, $2 and $3 freight rates, respectively.

Before analyzing these zones of superiority of one ship over

FIG. 7.



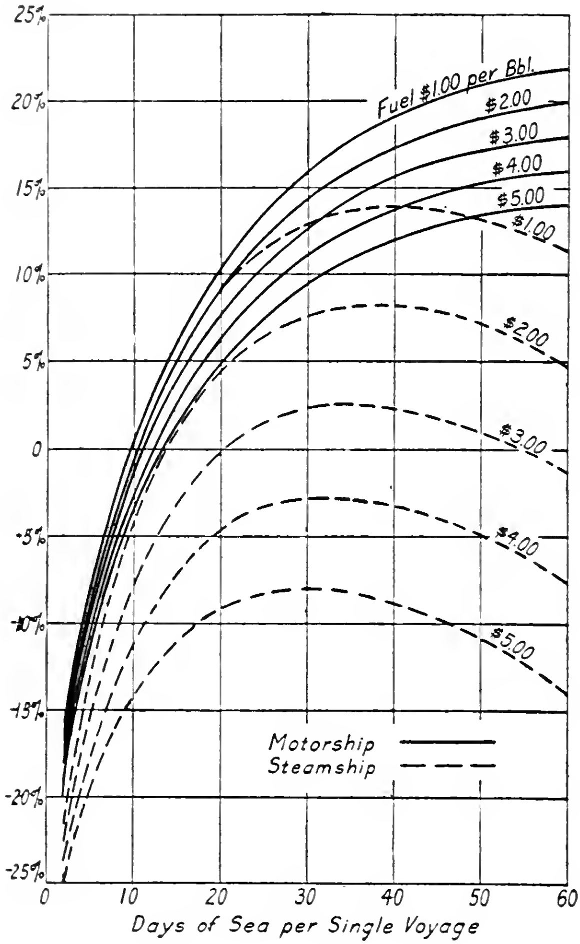
Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

the other, or the zones of competition where returns are substantially equal, it simplifies the work and strengthens the conclusions to examine into the relative importance of one freight rate, or one fuel price over the rest, and incidentally also to note that all results are based on the assumption of 20 days' stay in port.

With regard to port stay, it is clear that any other port stay that produces the same per cent. time in port or at sea, or the same

number of sea and port days per year, means the same thing. All the figures applying to the 20-day port stay with 10 days at sea, also apply to 30 days in port and 15 days at sea, and to

FIG. 8.



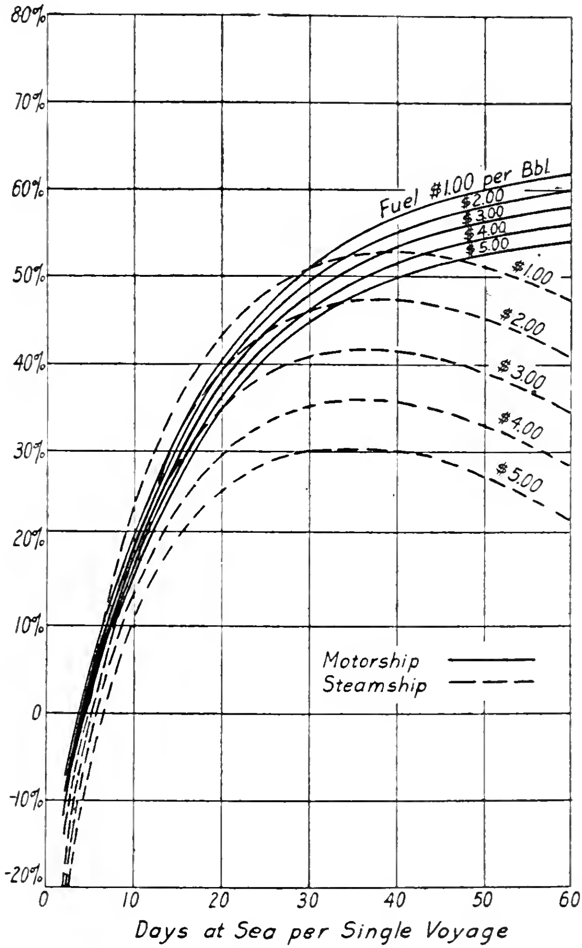
Annual Return on Investment with Freight Rate of $1.00 per 1000 Ton-Miles.

40 days in port with 20 days at sea. This extends all conclusions to any length of port days by selecting the appropriate number of sea days.

Freight rates per 1000 ton-miles are most variable items, fol-

lowing no fixed general rule and constantly fluctuating, but this is a matter of little consequence in comparing the profitable zones of two different ships so long as any fair or typical rate is selected to

FIG. 0.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

be applied to both. To arrive at such a rate, the quotations of the current month have been taken for heavy cargo of limited length, such as machinery, for example, and these rates are compared

TABLE X (A).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $1.00 per 1000 Ton-Miles.

Days per single voyage	Fuel at $1 per bbl. Dollars	Fuel at $1 per bbl. %	Fuel at $2 per bbl. Dollars	Fuel at $2 per bbl. %	Fuel at $3 per bbl. Dollars	Fuel at $3 per bbl. %	Fuel at $4 per bbl. Dollars	Fuel at $4 per bbl. %	Fuel at $5 per bbl. Dollars	Fuel at $5 per bbl. %
STEAMSHIP, $1,250,000										
5	-143,000	-11.44	-172,000	-13.76	-200,500	-16.00	-229,000	-18.32	-258,000	-20.64
10	- 20,000	-1.60	- 61,000	- 4.88	-102,000	- 8.16	-147,000	-11.76	-184,000	-14.72
20	110,000	8.80	53,500	4.28	- 2,500	- .20	- 58 500	- 4.68	-114,500	- 9.16
30	160,500	12.84	95,500	7.64	30,500	2.44	- 35,500	- 2.84	-100,500	- 8 04
40	174,000	13.92	102,500	8.20	31,000	2.48	- 40,500	- 3.24	-112,500	- 9.00
50	165,000	13.20	89,000	7.12	13,000	1.04	- 52,500	- 5.00	-138,000	-11.04
60	141,500	11.32	62,000	4.96	- 17,000	- 1.36	- 96,000	- 7.68	-175,000	-14.00
MOTORSHIP, $1,550,000										
5	-140,500	- 9.04	-150,000	- 9.64	-159,000	-10.23	-168,500	-10.83	-177,500	-11 40
10	- 5,500	- .35	- 19,500	- 2.50	- 33,500	- 2.15	- 48,000	- 3.09	-62,500	- 4.02
20	155,500	10.00	134,500	8.64	113,500	7.28	93,000	6.04	71,500	4.59
30	240,500	15.45	216,000	13.88	191,500	12.30	166,500	10.70	141,500	9.10
40	291,500	18.75	265,000	17.00	236,500	15.20	209,500	13.45	182,000	11.70
50	319,000	20.50	289,500	18.60	260,500	16.75	231,000	14.85	202,000	13.00
60	335,000	21.50	305,000	19.60	274,000	17.60	243,500	15.65	213,000	13.70

TABLE X (B).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $2.00 per 1000 Ton-miles.

Days per single voyage	Excess income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP, $1,250,000										
5	49,000	3.92	20,000	1.60	-8,500	-.68	-37,000	-2.96	-66,000	-5.28
10	287,000	22.96	246,500	19.72	205,500	16.44	164,500	13.16	123.500	9.88
20	539,500	43.16	483,000	38.64	427,000	34.16	371,000	29.68	315,000	25.20
30	636,000	50.88	571,000	45.68	506,000	40.48	440,000	35.20	375,000	30.00
40	659,500	52.74	588,000	47.04	516,500	41.32	445,000	35.60	373,000	29.84
50	639,000	51.12	563,000	45.04	487,000	38.96	411,500	32.92	336,000	26.88
60	590,000	47.24	511,000	40.88	432,000	34.56	353,000	28.24	274,000	21.92
MOTORSHIP, $1,556,000										
5	68,500	4.40	59,000	3.79	50,000	3.21	40,500	2.60	31,500	2.02
10	305,500	19.62	289,500	18.60	277,500	17.83	263,000	16.90	248,500	15.95
20	610,500	39.20	589,500	37.85	568,500	36.50	548,500	35.25	527,500	33.90
30	770,500	49.50	746,000	47.90	721,500	46.30	696,500	44.75	671,500	43.20
40	865,500	55.60	838,500	53.80	810,500	52.10	783,500	50.30	756,000	48.60
50	915,500	58.80	886,000	56.90	857,000	55.00	827,500	53.15	798,500	51.30
60	944,500	60.60	914,500	58.70	883,500	56.75	853,000	54.80	822,500	52.80

TABLE X (C).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $3.00 per 1000 Ton-miles.

STEAMSHIP, $1,250,000

Days per single voyage	Excess of income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
5	$ 239,000	19.12	$ 210,000	16.80	$ 181,500	14.52	$153,000	12.24	$124,000	9.92
10	594,000	47.52	553,500	44.28	512,500	41.00	471,500	37.72	430,500	34.44
20	969,000	77.52	912,500	73.00	856,500	68.52	800,000	64.00	744.500	59.56
30	1,111,500	88.88	1,046,500	83.68	981,500	78.48	915,500	73.20	850,500	68.00
40	1,145,000	91.60	1,073,000	85.84	1,002,000	80.16	930,000	74.40	858,000	68.64
50	1,113,000	89.04	1,037,000	82.96	961,000	76.88	886,000	70.88	810,000	64.80
60	1,040,000	83.20	960,000	76.80	881,000	70.48	802,000	64 16	723,000	57.84

MOTORSHIP $1,556,000,

Days per single voyage	Fuel at $1 Dollars	%	Fuel at $2 Dollars	%	Fuel at $3 Dollars	%	Fuel at $4 Dollars	%	Fuel at $5 Dollars	%
5	$ 237,500	15.27	$ 228,000	14.65	$ 219,000	14 10	$ 209,500	13.47	$ 200,500	12.90
10	616,500	39.40	602,500	38.70	588,500	37.80	574,000	36.90	559,500	35.90
20	1,065,500	68.40	1,044,500	67.10	1,023,500	65.75	1,003,000	64.30	982,500	63.15
30	1,300,500	83.50	1,276,000	81.90	1,251,500	80.40	1,226,500	78.75	1,201,500	77 50
40	1,439.500	92.40	1,412,500	90.70	1,384,500	88.90	1,357,500	87.10	1,330,500	85.50
50	1,511,500	97.20	1,482,500	95.20	1,453,500	93.30	1,423,500	91.40	1,394,500	89.50
60	1,554,000	100.00	1,523,500	97.90	1,493,000	95.90	1,462,500	93.90	1,432,000	92.00

TABLE XI.

Per Cent. Investment Return Compared

For

(a) Geared Turbine Single Screw 3500 S. H. P. Steam Auxiliaries

(b) Diesel Direct Twin Screw Diesel Electric Auxiliaries

Days per single voyage	Freight Dollars 1000 Ton-miles	Fuel $1.00		Fuel $2.00		Fuel $3.00		Fuel $4.00		Fuel $5.00	
		Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel
5	$1.00	-11.44	- 9.04	-13 76	- 9.64	-16.00	-10.23	-18.32	-10.83	-20.64	- 11.40
	2.00	3.92	4.40	1.60	3.79	- .68	3.21	-2.96	2.60	- 5.28	2.02
	3.00	19 12	15.27	16.80	14.65	14.52	14.10	12.24	13.47	9.92	12.90
10	1.00	- 1.60	- .35	- 4.88	- 2.50	- 8.16	- 2.15	-11.76	- 3.09	-14.72	- 4.02
	2.00	22.96	19.62	19.72	18.60	16.44	17.83	13.16	16.90	9.88	15.95
	3.00	47.52	39.40	44.28	38.70	41.00	37.80	37.72	36.90	34.44	35.90
20	1.00	8.80	10.00	4.28	8.64	- .20	7.28	- 4.68	6.04	- 9.16	4.59
	2.00	43.16	39.20	38.64	37.85	34.16	36.50	29.68	35.25	25.20	33.90
	3.00	77.52	68.40	73.00	67.10	68.52	65.75	64.00	64.39	59.56	63.15
30	1.00	12.84	15.45	7.64	13.88	2.44	12.30	- 2.84	10.70	- 8.04	9.10
	2.00	50.88	49.50	45.68	47.90	40.48	46.30	35.20	44.75	30.00	43.20
	3.00	88.88	83.50	83.68	81.90	78.48	80 40	73.20	78.75	68.00	77.50
40	1.00	13.92	18.75	8.20	17.00	2.48	15.20	- 3.24	13.45	- 9.00	11.70
	2.00	52 74	55.60	47.04	53.80	41.32	52.10	35.60	50.30	29.84	48.60
	3.00	91.60	92.40	85.84	90.70	80.16	88.90	74.40	87.10	68.64	85.50
50	1.00	13.20	20.50	7.12	18.60	1.04	16.75	- 5.00	14.85	-11.04	13.00
	2.00	51.12	58.80	45.04	56.90	38.96	55.00	32.92	53.15	26.88	51.00
	3.00	89.04	97.20	82.96	95.20	76.88	93.30	70.88	91.40	64.80	89.50
60	1.00	11.32	21.50	4.96	19.60	- 1.36	17.60	7.68	15.65	14.00	13.70
	2.00	47.24	60.60	40.88	58.70	34.56	56.75	28.24	54.80	21.92	52.80
	3.00	83.20	100.00	76 80	97.90	70.48	95.90	64.16	92.00	57.84	92.00

TABLE XII.

Freight Rates.

Data from "MARINE REVIEW," April, 1921.

Zone	Place	Distance, miles	General cargo	Heavy products, limited length	Per 1000 ton-miles	
					General	Heavy
England	London	3442	$ .75 per 100 lb.	$ 8.00 per ton	4.88	2.33
North Sea	Christiana	3771	1.25 per 100 lb.	10.00 per ton	7.43	2.65
	Rotterdam	3488	1.00 per 100 lb.	6.00 per ton	6.42	1.72
	Antwerp	3487	.80 per 100 lb.	5.00 per ton	5.13	1.43
Mediterranean	Marseille	3913	22.00 per ton	12.00 per ton	5.63	3.07
	Naples	4200	1.00 per 100 lb.	12.00 per ton	6.40	2.86
	Constantinople	5044	26.00 per ton	18.00 per ton	5.15	3.87
S. Africa	Capetown	6786	27.00 per ton	20.00 per ton	3.98	2.95
S. America, E.	Buenos Aires	3871	20.00 per ton	12.00 per ton	3.40	2.04
	Rio Janerio	4770	22.50 per ton	16.50 per ton	4.71	3.46
S. America, W.	Valparaiso	4633	1.33 per 100 lb.	16.00 per ton	6.39	3.45
Australia	Sydney	9691	25.00 per ton	15.00 per ton	2.58	1.55
India	Calcutta	9834	21.00 per ton	18.00 per ton	2.13	1.83

in Table XII, with each other for a number of scattered ports, and with the corresponding rates for general cargo.

The former are more consistent and charges lower, and range from about $1.50 to $3.50, with $2 as a fair average. When the ship has less than a full cargo, all conclusions drawn for full cargos apply with equal force to a correspondingly lower rate. For example, if conclusions are drawn on a $3 freight rate, assumed for a full ship, and the ship sails full one way, returning in ballast, or carries half cargo both ways, then the effect can be judged from the curves for a rate of $1.50 applied to full cargo. Normally,

TABLE XIII.

Fuel Oil—Present Indicative Prices.

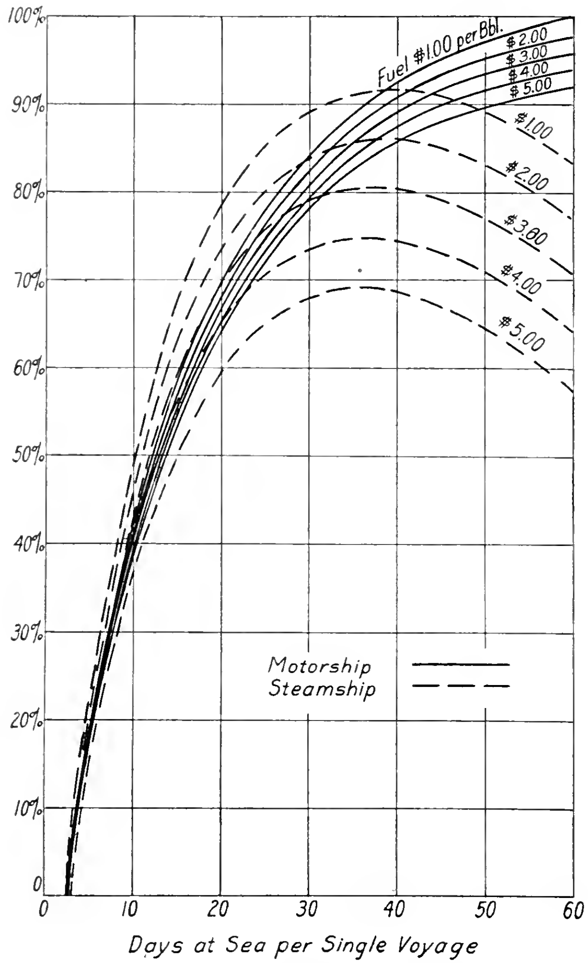
Zone	Cost per American bbl. 42 gals. Dollar	
	Oil Company A	Oil Company B
U. S. North Atlantic	......	3.00
U. S. Gulf	......	1.35 - 1.85
U. S. Pacific	......	2.00 - 2.85
Great Britain	4.02 - 4.59	4.14
North Sea	4.82	......
Mediterranean	4.31	6.06
South Africa	5.54	......
South America, E.	5.01 - 5.46	5.40
South America, W.	......	5.00
Australia and Australasia	5.75	......
Asia	5.01	6.06

the longer the voyage the lower the freight rate, which is as it should be, because costs are less.

Fuel oil prices at the present time for various parts of the world are collected in Table XIII, and indicate that for the United States, in round numbers, with the exception of a few Gulf ports, the price is $2 to $3 per bbl., with the $3 price prevailing where the bulk of the traffic concentrates on the North Atlantic coast. For European ports the price in round numbers is $4 per bbl. For the rest of the world, South America, Africa, Asia and Australia, the price is $5 or over. These are the significant price ranges, *i.e.*, $3 to $5 per bbl., and former prices of $1 per bbl. or less no longer have any importance. An analysis of fuel oil prices in the past will indicate a steady rise and in recent years a rise controlled by the demand for automobile gasolene, such

that fuel oil follows gasolene in price at a pretty constant fraction, and probably always will do so. The future trend is definitely upward in spite of fluctuations natural to alternations

FIG. 10.



Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

of business activity or stagnation. For these reasons the higher prices are the most significant in drawing conclusions as to the future with regard to the relative earning capacities of the different types of ships *over their life periods.*

Conclusions can now be drawn from the figures for investment returns of Table X and the corresponding superimposed curves of Figs. 8, 9, 10.

Starting with the fuel price of $3 per bbl. and a freight rate of $1 per 1000 ton-miles, it appears that the steamer shows a loss for voyage lengths less than 20 days, and the motorship for less than 10 days. The motorship is consistently the more profitable, yielding returns, compared to the steamer, increasing with length of voyage, 12.3 per cent. *vs.* 2.4 per cent. for 30 days, 15.2 per cent. *vs.* 2.5 per cent. for 40 days, 16.8 per cent. *vs.* 1.0 per cent. for 50 days, and 17.6 per cent. *vs.* a loss of −1.4 per cent. for 60 days, respectively.

For the $2 freight rate, the steamer shows a loss under 5 days, and the motorship no loss. The motorship earnings compete with the steamer on about equal terms, with the latter a little better for voyages of 20 days or less, after which the motorship earnings increase over the steamer, the relation being, 52.1 per cent. *vs.* 41.3 per cent. for 40 days, 55 per cent. *vs.* 39.0 per cent. for 50 days, and 56.7 per cent. *vs.* 34.6 per cent. for 60 days.

With a $3 freight rate, the two ships are competitive on about an equal earning basis for voyages up to about 30 days, after which the motorship earnings increase over the steamer, the figures being, 89 per cent. *vs.* 80 per cent. for 40 days, 93 per cent. *vs.* 77 per cent. for 50 days, and 96 per cent. *vs.* 70 per cent. for 50 days.

At the higher fuel price of $4 per bbl. for fuel oil, the competitive zone is narrowed to shorter voyages at corresponding freight rates.

For a freight rate of $1, the steamer shows a loss for any length of voyage and the motorship for less than 10 days. The motorship returns increase regularly beyond, 6 per cent. for 20 days, 11 per cent. for 30 days, 14 per cent. for 40 days, 15 per cent. for 50 days and 16 per cent. for 60 days' voyage.

Freight rates of $2 reduce the steamer losses to less than 5 days and eliminate loss of the motorship. The motorship is consistently more profitable over the whole range, as shown by the figures: 17 per cent. *vs.* 13 per cent. for 10 days, 35 per cent. *vs.* 30 per cent. for 20 days, 45 per cent. *vs.* 35 per cent. for 30 days, 50 per cent. *vs.* 36 per cent. for 40 days, 53 per cent. *vs.* 33 per cent. for 50 days, 55 per cent. *vs.* 28 per cent. for 60 days.

A further increase of freight rates to $3 widens the competitive

zone further, the two ships being on about an equal basis for voyages less than 20 days beyond which the motorship is increasingly profitable, the figures being, 79 per cent. *vs.* 73 per cent. for 30 days, 87 per cent. *vs.* 74 per cent. for 40 days, 91 per cent. *vs.* 71 per cent. for 50 days, and 94 per cent. *vs.* 64 per cent. for 60 days.

Taking the fuel oil price of $5 per bbl. the importance of economy is greater.

For a freight rate of $1, the steamer shows a loss for any length of voyage, but the motorship yields net returns for voyages in excess of 10 days, and in increasing amounts, the figures being 5 per cent. for 20 days, 9 per cent. for 30 days, 12 per cent. for 40 days, 13 per cent. for 50 days and 14 per cent. for 60 days.

Freight rates of $2 eliminate the steamer losses for voyages over 5 days and increase the motorship profits materially over the steamer, the figures being, 16 per cent. *vs.* 10 per cent. for 10 days, 34 per cent. *vs.* 25 per cent. for 20 days, 43 per cent. *vs.* 30 per cent. for 30 days, 49 per cent. *vs.* 30 per cent. for 40 days, 51 per cent. *vs.* 27 per cent. for 50 days, 53 per cent. *vs.* 22 per cent. for 60 days.

Finally at $3 freight rate, the motorship is consistently more profitable than the steamer over the whole range of voyage lengths, the figures being, 13 per cent. *vs.* 10 per cent. for 5 days, 36 per cent. *vs.* 34 per cent. for 10 days, 63 per cent. *vs.* 59 per cent. for 20 days, 78 per cent. *vs.* 68 per cent. for 30 days, 86 per cent. *vs.* 69 per cent. for 40 days, 90 per cent. *vs.* 65 per cent. for 50 days, 92 per cent. *vs.* 58 per cent. for 60 days.

This analysis proves conclusively the practicability of this method of analysis, and fixes the competitive and non-competitive zones in terms of voyage lengths for the two forms of present new standards of ship propulsion with geared turbine steamer, single-screw, with steam auxiliaries, and the twin-screw motorship with direct-coupled Diesel engines and Diesel electric auxiliaries. It clearly shows the importance of freight rates and fuel prices, on the relative profitable zones of operation. High fuel prices and low freight rates favor the motorship as do also long voyages.

One most remarkable conclusion is that the motorship has a very sharply defined zone in which the turbine steamer cannot compete at all, the long voyage, low freight rate, high fuel price zone. On the other hand, there does not appear to be any such

well defined zone where the steamship could be said to dominate. The steamship economic zone is that of short voyages, of a few days at normal freight rates and fuel prices, and even for these conditions the motorship returns are never very much below the steamer. This means in effect that when the motorship does not control, it is at least competitive actually or so very nearly so unless fuel prices fall very low, less than a dollar per barrel.

When the length of voyage is very short, only a few days, a condition that favors the steamer over the motorship, it must be remembered that the ratio of port time to sea time becomes so abnormally large as to lead inevitably to the conclusion that such a large ship as is under consideration, 10,000 D.W.T., is unsuited to the service, which really requires a smaller vessel, small enough to shorten port time to an acceptable value. As ships grow small, 5000 D.W.T., and less, the oil engine has proportionately greater advantages over steam. It is only in those cases where the conditions keep a ship in port most of the time that the cheapest kind of steamer is the only thing that will meet the requirements, and fuel expense at sea becomes a minor item, with a good probability that coal-fired boilers must be used.

Changes in expense items due to different estimates of quantities and prices from those used will have the effect of changing the competitive zones of the two types of ships under analysis by a few days, but will have no other effect on the general conclusions that have been reached as to relative economic zones.

(To be concluded)

The Wave-length of Hard Gamma Rays. A. H. COMPTON. (*Phil. Mag.*, May, 1921.)—A new method for the calculation of wave-lengths is developed, which depends upon the finding of an angle at which the ratio of the gamma rays scattered from lead to those scattered from copper is the same as the ratio of X-rays scattered at 90° from lead to those scattered from copper. When this angle has been found a simple formula gives the desired wave-length, provided the wave-length of the X-rays is known. There are elements of uncertainty in the process, but the author feels justified in giving for the wave-length of hard gamma rays that have traversed 8 mm. of lead the quantity .025 to .030 angstrom units. This is only about one two-hundred-thousandths of the wave-length of sodium light. (An angstrom unit is one ten-millionth mm.) G. F. S.

Manufacture of Engines, Steam, Gas and Water.—A preliminary statement of the 1920 census of manufactures with reference to the manufacture of engines, steam, gas and water, has been prepared by the Bureau of the Census, Department of Commerce. It consists of a detailed statement of the values of the various products manufactured during the year 1919.

The figures are based on returns from 371 establishments with products for the year valued at $464,770,000. At the census of 1914 there were 446 establishments with products valued at $72,121,000.

In 1919, 44 establishments were located in Ohio; 36 in Wisconsin; 35 in Michigan; 34 in Pennsylvania; 31 in New York; 25 in Illinois; 22 in California; 17 in Iowa; 16 each in Connecticut and Indiana; 15 in New Jersey; 14 in Minnesota; 13 in Washington; 10 in Missouri; 5 in Kansas; 4 in Massachusetts; 3 each in Colorado, Maine, Maryland, Oregon, and Texas; 2 each in Kentucky, Nebraska, and New Hampshire; and 1 each in Alabama, Arkansas, Delaware, Florida, Louisiana, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, and Virginia.

Of the total establishments under this classification the chief product of 60 was steam engines; of 199, internal combustion engines; of 85, traction engines; of 10, water wheels, motors, turbines and hydraulic rams; and of 17, locomotive engines, parts of engines and locomotives, and other foundry and machine shop products and repairs.

World's Largest Deposit of Rock Salt.—Vast quantities of rock salt lie less than half a mile beneath the surface of the earth in the United States. In New York, Ohio, Michigan, Pennsylvania, West Virginia, and other States there are large deposits, but the largest deposit in the United States, and probably in the world, is that which extends from northern Kansas across the west end of Oklahoma, the panhandle of Texas, and southeastern New Mexico to western Texas. The area underlain by these great Permian salt deposits is not far from 100,000 square miles, according to the U. S. Geological Survey. The limits of the deposit, especially to the northwest and southeast, have not been ascertained, but in general the area of thick salt extends fully 650 miles from northeast to southwest, and is 50 to 150 miles wide. The thickness and the succession of the beds are variable, but 700 feet is reported in one hole, and in many places the aggregate is more than 300 feet. On the assumption of an average thickness of 200 feet of salt, the gross quantity in the area of 100,000 square miles is so large, about 30,000 billion tons, that the present needs of the United States (about 7,000,000 tons a year) can be supplied for millions of years.

LEONARDO DA VINCI—NATURAL PHILOSOPHER AND ENGINEER.* †

BY

JOHN W. LIEB, M.E.

Vice President, the New York Edison Company. Member of the Institute.

We have no single architectural structure which can be claimed as the authentic work of Leonardo, although his manuscripts are full of sketches and plans for all kinds of buildings, public and private. We have some reason to believe that he coöperated with Bramante in the planning of several buildings, and we have definite knowledge that he made plans and acted as a consulting architect on the Cathedral at Milan and that he executed the frescos recently restored in some of the rooms of the Castello Sforzesco, Milan, and probably did some of the planning on that formidable medieval castle-fortress. We also know that he was frequently consulted as an expert in building, and he has written many notes on the construction of foundations and the causes of fissures and cracks in walls. In his introduction to these notes he says: " First write the treatise on the causes of failure of walls and then separately treat of the remedies." Of foundations, Leonardo says:

> " The first and most important thing is stability. As to the foundations of the component parts of temples and other public buildings, the depths of the foundations must bear the same proportions to each other as the weight of the material which is to be placed upon them." Bm Fol 138a

And again:

> " That beam which is more than twenty times as long as its greatest thickness will not last long, but will break in half; and remember that the part built into the wall should be steeped in hot pitch and filleted with oak boards likewise so steeped. Each beam must pass through its walls and be secured beyond the walls with sufficient chaining, because in consequence of earthquakes the beams are often seen to come out of the walls and bring down the walls and floors. Again I remind you never to put plaster over timber, since by expansion and shrinking of the timber produced by damp and dryness such layers often crack, and once cracked their separation gradually produces dust and an ugly effect." Ms A Fol 53a

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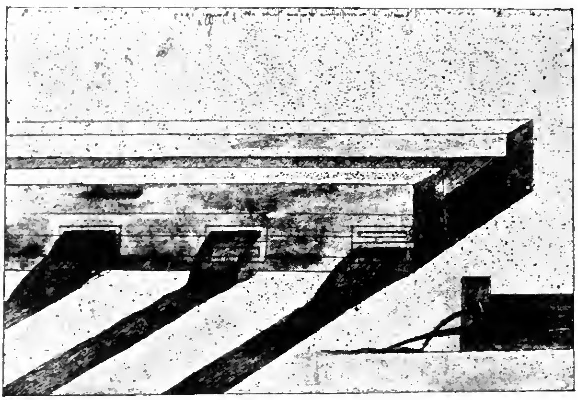
* Presented at the Annual Meeting of the Institute held Wednesday, January 19, 1921.

† Concluded from page 806, vol. 191, June, 1921.

We have sketches in perspective and some in plan and elevation showing the internal arrangements of palaces and villas, sketches of several battlemented castles, an elaborate mausoleum, a project for raising the Baptistry of Florence, and a great number of churches and Basilicas.

Leonardo also made a most interesting study of city planning, including a plan for a town with a double system of high level and low level roadways. In this connection we find a suggestive note:



Canal of S. Cristoforo, Milan. Measurement of water.

"Let the street be as wide as the average height of the houses." Ms B Fol 36r

This dream of a model city is thus referred to:

"The model cities will be served by two kinds of streets; highways elevated or on a slope, elegantly ornamented and perfectly clean; and lower or subterranean roadways, washed from time to time by limpid water from the watercourse, and from which the refuse will be removed with rakes.

In such a way that whoever wishes to travel by the elevated highway may do so at will; and also whoever wants to go by the lower route will be free to do so. Vehicles will never make use of the upper highway, reserved for gentlemen; while in the lower street the wagons and beasts of burden for work and for the supplies of the people will circulate." Ms B Fol 16r

The plague had ravaged Milan during the years 1484 and 1485, causing the death of over 50,000 people and destroying all commerce and all activity; Leonardo wished to reconstruct the city and the surrounding towns which had been decimated by the scourge and he wrote to the Duke:

"Lay out again 5000 houses among 10 cities, corresponding to 30,000 lodgings and you will thus split up the masses of population that now crowd together like goats, side by side, scattering over all the fetidity and the pestilential germs of death. The cities will be beautiful and you will be honored for it forever." Ms CA Fol 65v

A careful study of the notes and sketches shows that Leonardo devoted considerable time and thought to the elimination of unnecessary work in construction, and to obtaining the maximum result with a minimum of effort; in reality this is what we term to-day motion study as applied to the industries.

We find many references to the excavation by machines and men of canals and trenches, and that he did not neglect the smallest detail is shown by diagrams of ditch digging on four levels, the men being shifted from one level to another so that each man will not be performing the most laborious work all of the time. And this, he says, "gives better results."

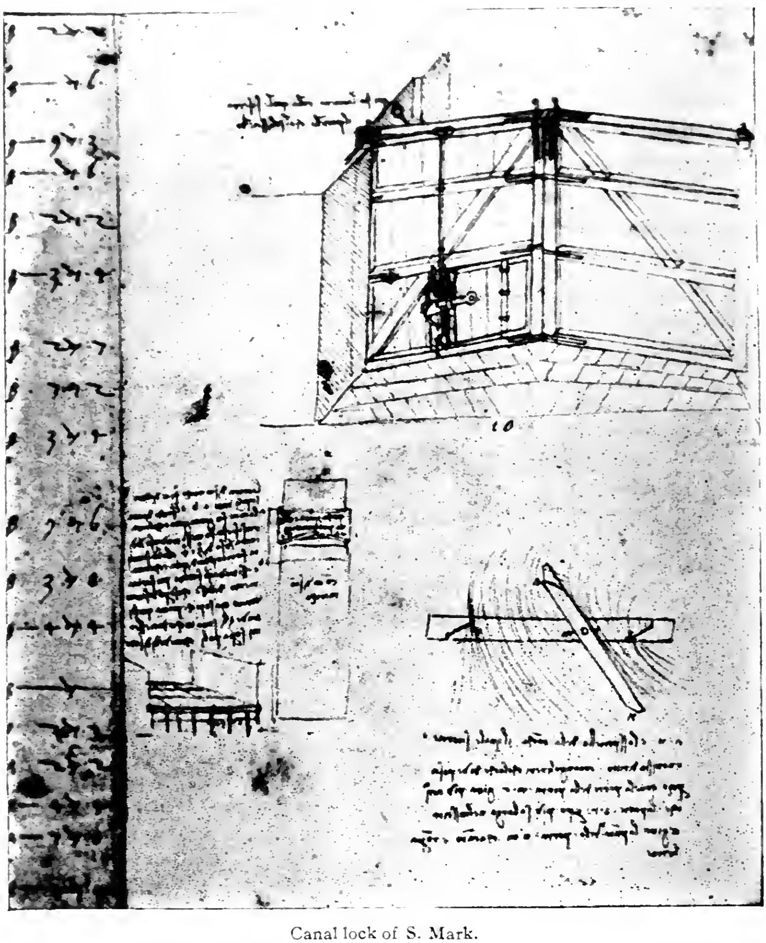
He investigated also the motions involved in carrying materials by means of carts, and a century and a half before Pascal, to whom is attributed the invention of the wheelbarrow, Leonardo actually applied it in the transportation of earth, stones and water.

One sheet of Leonardo's notes contains, among other excavating tools, sketches showing the evolution of the wheelbarrow, starting with the primitive form, in which the load was fastened to a long pole dragged along the ground, and leading up to the device as we now make use of it. It is interesting to note that he describes many methods in common use to-day, such as the travelling bucket which carries earth to a desired place and is then emptied by pulling a rope. This method he advocated, instead of lifting the earth to an upper level by means of a winch and then carrying it by hand to the place where it was to be discharged, which was the method in common use at that time.

For the operation of each crane of the excavating machine, six men were necessary—four who fill the bucket and two who bring down the counterweight by the weight of an ox, thus raising the bucket. The bucket empty and the crane turned, the bucket is then swung around and lowered again to the bottom. The lower figure shows another stairway which Leonardo says is better, since being curved, its base is half the distance from the foot of the crane that the straight stairway is, and the ox can make an increased number of trips a day.

A hundred years before Galileo, who previously was accredited with this service to structural mechanics, Leonardo made careful investigations on the strength of materials.

In his treatise Leonardo states that the load capable of being



Canal lock of S. Mark.

carried by a cantilever is inversely proportional to the distance from the load to the point of support.

He says:

"If you place upright a support of uniform thickness and material, which will resist a weight of 100, and you then take 9-10ths of the height away, you

will find that the rest when stood on end will resist a weight of 1000." Ms CA Fol 152 and 211

And of horizontal beams loaded at the centre:

"You will find a similar strength and resistance in a bundle of nine beams of equal cross section, as in the one-ninth part of one of them." Ms CA Fol 152 and 211

And to test the strength of wire Leonardo shows a crude wire-testing machine in which the weight is applied gradually by means of sand dropping into a pail.

HYDRAULIC ENGINEERING.

Leonardo's work in Hydraulic Engineering was of a theoretical as well as a practical character, and the results of his experiments and observations are embodied in the treatise "On the motion and measurement of water," a complete text-book on hydraulics which treats nearly every phase of the subject. The science of hydraulics had its birth in Italy and Venturi says of da Vinci's work: "Not only did he observe all that Castelli wrote about the movement of water a century later, but he was his superior, although Castelli has until now been considered the founder of hydraulics."

He begins his treatise in truly modern style with an index of subjects, a series of definitions of the terms used and a vocabulary of technical words and phrases.

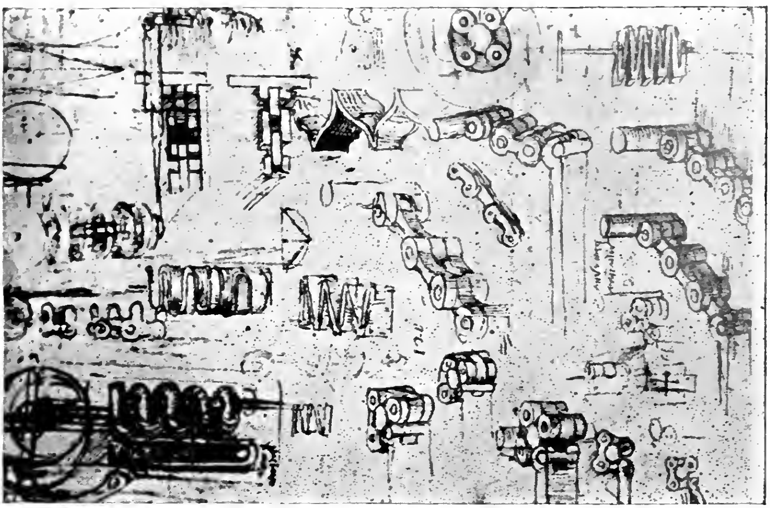
It treats of the physical properties of water, the forms it assumes as clouds, rain and drops, the flow of water in canals and rivers, the distribution of the currents caused by the shape of the river bed and shores, the formation of waves, vortices, whirlpools and eddies, and the measurement of the velocity and volume over weirs and through orifices.

The illustrations of the complicated figures which water makes when it is contracted into whirls and eddies flowing from a spout, a discharge nozzle or over a dam into a basin or river with the various interference currents, counter-currents and reflected waves, cover many pages of his notes.

His studies cover also the erosion of river banks and methods of protecting water courses, the transportation of rocks, gravel and sand from the mountains to the sea, and a discussion of methods of measurement and finally the application of pumps of

every conceivable kind, Archimedian screws, chain and bucket lifts, and even the beam type of suction pump with double acting valves, for the elevation of water and the reclaiming of marsh lands, all these investigations and plans being directed into practical channels, as witness their extensive application by him in canals for irrigation and transportation with their locks, gates and distribution sluices.

Leonardo was appointed water register for Lombardy by the King and he obtained as a gift the right to divert a certain quan-



Sprocket chains.

tity of water from the St. Cristoforo Canal, Milan, part of which he expected to sublet and part to be used for irrigation on his own property, and he refers to this franchise grant as follows:

> "If it is said that the income of the King is reduced 72 ducats by taking that water from St. Cristoforo, His Majesty knows that what he gives to me he takes from himself, but in this case nothing is taken from the King, but taken from those who have stolen, because in arranging the sluices they have stolen the water by enlarging them." Ms CA Fol 93r

We find many interesting sketches of waterways and canals crossing over rivers on special arched bridges, and he presents plans for extensive reclamation work in Tuscany, inland waterways and a plan for the Romortin Canal in France, which was

actually carried out in accordance with his scheme centuries later.

An interesting note on canal construction merits translation in full. Referring to the Romortin Canal in France:

"The water may be dammed up above the level of Romortin to such a height, that in its fall it may be used for numerous mills. The river at Villefranche may be conducted to Romortin which may be done by the inhabitants; and the lumber of which their houses are built may be carried in boats to Romortin. The river may be dammed up to such a height that the waters may be brought back to Romortin with a convenient fall." Ms BM Fol 269b

And also on the Canal of Florence:

"Sluices should be made in the valley of La Chiana at Arezzo, so that when, in the summer, the Arno lacks water, the canal may not remain dry; and let this canal be 20 braccia (yards) wide at the bottom and at the top 30, and 2 braccia deep, or 4, so that 2 of these braccia may flow to the mills and the fields which will benefit the country; and Prato, Pistoia and Pisa, as well as Florence, will gain two hundred thousand ducats a year, and will lend a hand and money to this useful work; and Lucca the same, for the Lake of Sesto will be navigable; I shall direct it to Prato and Pistoia and cut through Serravalle and make an issue into the lake; for there will be no need of locks and supports, which are not lasting and so will always be giving trouble in working at them and keeping them up." Ms CA Fol 45a–140a

"If it be not reported that this is to be a public canal it will be necessary to pay for the land; and the King will pay it by remitting the taxes for a year." CA 233a; 700a

He gives illustrations and describes in notes various kinds of divers' helmets and air hose for the use of divers, life preservers and queer devices for swimming and walking on the water. In this connection he says:

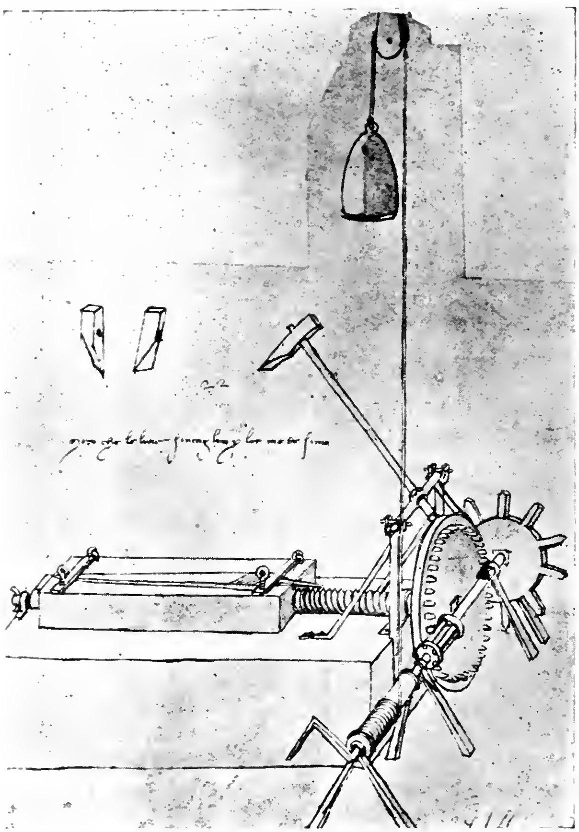
"It is necessary to have a coat made of leather with a double hem over the breast the width of a finger and double also from the girdle to the knee and let the leather of which it is made be quite air-tight. And when you are obliged to jump into the sea, blow out the lapels of the coat through the hems at the breast and then jump into the sea. And always keep in your mouth the end of the tube through which the air passes into the garment, and if once or twice it should become necessary for you to take breath when the spray prevents you, draw it through the mouth of the tube from the air within the coat." Ms B Fol 81b

MECHANICAL ENGINEERING.

In the field of mechanical engineering, particularly, Leonardo did a vast amount of what seems to have been pioneer work, and the engineer of to-day in studying his notes and drawings, becomes deeply impressed with the close touch in which he is put with

this earliest of mechanical engineers, through the medium of that international engineering language, a working mechanical drawing.

While we find in the ancients a knowledge and application of the elemental mechanical movements, the lever, the inclined plane, the pulley and the screw, and to an extent their simple combina-



File cutting machine.

tion, it is in the work of this master mind that we first reach the full fruition of mechanical genius.

In his work we first find exemplified complex mechanical movements of the most ingenious kinds, then their combination to achieve desired motions and finally, their coördination into a complete working machine, the various functions of the machine correlated by appropriate mechanism, often automatic in its opera-

tion, for let it be said he was indeed the very first, as far as we know, to introduce the really modern element of automaticity into his machines.

The improvements suggested in machines having an axis of rotation are of marked interest, for he designed shafts to turn not only in adjustable stationary bearings, but with roller bearings as we have them to-day, to reduce friction. Flexible chain or sprocket drive are among his inventions and they are clearly shown on several sheets of the Codice Atlantico together with flat chains of even mesh, not soldered, flexible only in the two opposite directions, to be used instead of belts for the transmission of power in machines.

The character of his sketches of cranks, pins, couplings, cams, friction clutches and gears show that the subject of our address had for his time a remarkably accurate knowledge of machine design and construction, and some of the framework and supports of his apparatus are of excellent design.

We have among his sketches a remarkable series of machines to only a few of which reference can be made:

An automatic file-cutting machine presents interesting details including the mechanism for feeding forward the steel blank as the teeth are cut, the hammer heads for various cuttings, the mechanism for operating the machine by a heavy falling weight, etc. We find illustrated several machines, horizontal and vertical, for drilling pump logs excellently designed like a modern boring lathe, and remarkable to relate, one of the forms shows an automatic geared chuck, a modern tool that was reinvented and patented as new not so many years ago.

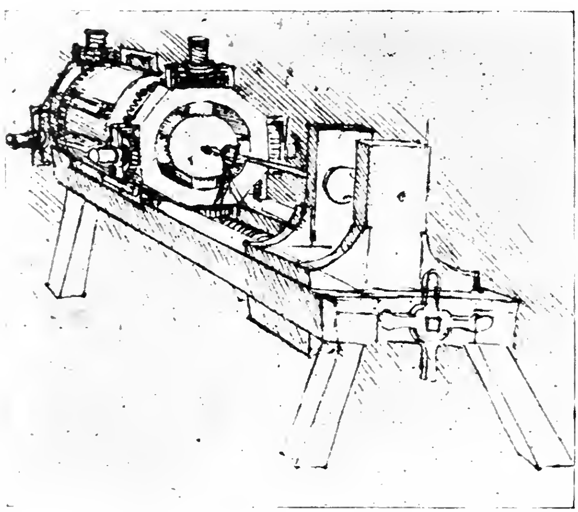
A truly wonderful piece of mechanism is the machine driven, as shown, by a turbine water wheel for drawing tapering trapezoidal iron bars for built-up cannon in which should be noted particularly the feeding mechanism and the helicoidal rotating die for producing the taper and the trapezoidal draw blocks. We find sketches of many machines for drawing wire, bars and flat springs.

Many sketches illustrate grinding machines of various kinds for grinding colors and for grinding lenses of different focal lengths and even parabolic lenses. Leonardo invented the three-legged folding stool, the hinge with spiral spring for automatically shutting the door, secret or unpickable locks, rotating chimney tops for smoke pipes, and a turnspit operated by hot air, of which

he says: "This is the true turnspit because according as the fire is moderate or not, the roast will turn quickly or slowly." Ms CA Fol 5va

We have also various types of windlasses, capstans and cranes; mechanical presses, machines for weaving ribbon, for cutting cloth, and for spinning silk and linen.

He produced a complete set of coin stamps for the Royal Mint at Rome and shows the blanks and describes their manipulation. We also find rolling mills for sheet lead, several kinds of turning



Boring mill for pump logs.

lathes operated by weights and by foot power, various kinds of saws for stone and wood operated by crank and connecting rod and with flywheels to secure uniformity of motion.

He speaks of the use of the pendulum as a speed regulator; shows an automatic printing press, a drop or punching press, screw-cutting machines to cut screws of various pitches with a master screw and cutting tool and change gears, rope-making machinery and complicated machines for pointing needles.

In the textual notes, accompanying many of these machines, some having no marginal notes with the purpose of the machine therefore sometimes left in doubt, appear some interesting reflections as to the power taken by the machines and other peculiari-

ties, for instance: "These machines must be driven by water power, for when they are turned by hand they go so slow that the work is not effective," and "Because without experiment a correct understanding of the power with which the drawn iron resists the die cannot be obtained, I have made in the doubtful parts four wheels with endless screws, by means of which anyone can tell by observing their size what power the combination has."

"If you do not wish to multiply the number of teeth of the wheels, then increase their size, which will give the same thing." "The rope for the above hydraulic machine must be of iron or annealed copper wire, otherwise it is of little strength; and the above mentioned wire must be of the thickness of a bow string."

He occupied himself much with the design and construction of spinning machinery and in all of his designs it is clear that he laid special emphasis on the relative motions of the spindle and the spool.

Leonardo is believed to have been the inventor of the flyer, operating in conjunction with the spindle for twisting the yarn in the process of winding it on the bobbin as used in the present-day spinning frames.

It is certainly remarkable that use was made of the reverse spindle and spool movements quite as they are used to-day in our automatic machines and that he understood how to combine the rotating motion of the spindle with an alternating motion.

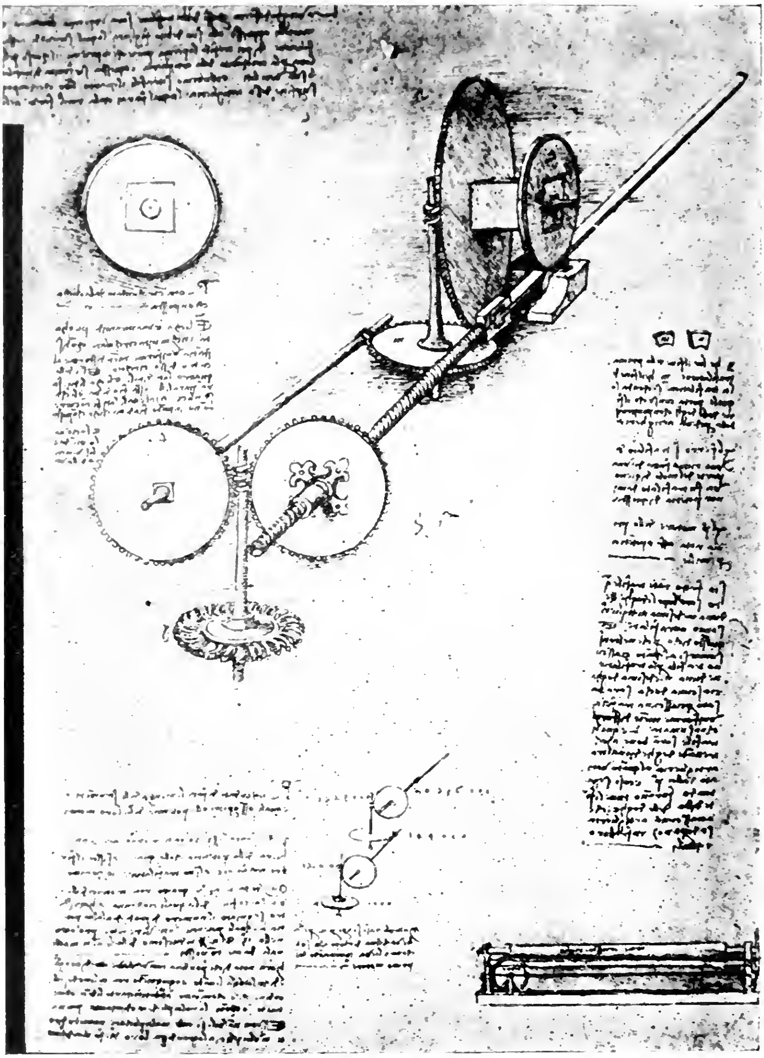
He shows sketches of a hygrometer, a cyclometer applied to a wagon, an adometer and also a pedometer, a universal compass suspension, a universal joint, a dynamometer and a spring-driven automobile!

We have also a complete sketch of a friction fire escape, re-invented only a few years ago, in regard to which there is a marginal note which says:

> "This device is made to enable one to drop quickly from great heights without danger of fall. The rope—c, d—is given three turns around the screw—a, b—. This screw is 1/2 elle long and 1/12 elle thick. This is then covered with the cylinder—e, f—thus tightening the grip and increasing the friction which allows of only a slow drop when one hangs on the screw." Ms CA Fol 112rb

We should also note the designs of several types of water wheels overshot and undershot and also a diagrammatic sketch of a pressure water turbine.

Enough has been said to show what a marvelous range is covered by these sketches and mechanical drawings, many of them



Machine for drawing bars for cannon.

in perspective and executed with great precision, not only as to their draughtsmanship, but as to their good proportioning of parts and general excellence of design from an engineering standpoint.

ARTIFICIAL FLIGHT.

And now we come to a most interesting field—a very new and modern field—in which Leonardo did wonderful work, imaginative and speculative perhaps, but full of acute observation and experiment, a field in which he stopped just short of attaining practical results owing to the lack of that most important key to the solution of many of our problems of to-day and which has made possible the automobile, the dirigible, the aëroplane, and the speed boat—the internal combustion motor.

We refer to Leonardo's work in the field of artificial flight. In no other direction has he shown such a combination of the extraordinary powers he possessed of scientific research, acute observation and mechanical ingenuity. Without the internal combustion motor we have to-day, aviation would be just about where he left it, with the possible exception of the work done on gliders by Chanute and Lilienthal.

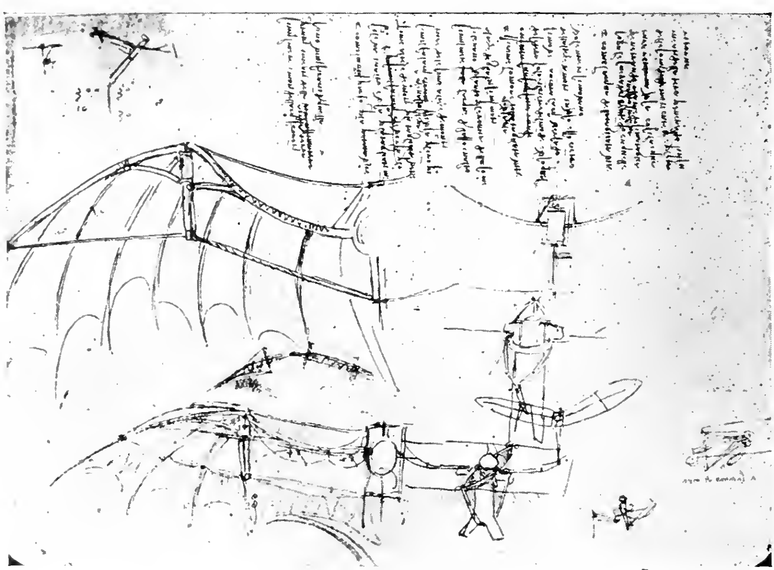
If we were to go into the details of his observations on the flight of birds, and every creature that flies, his researches and investigations on wind pressure, shape of wings, balancing, etc., the design and suggestion for flying machines with the wealth of details of construction of wings and tails and operating mechanism as revealed in his numerous sketches and notes, we should take up for this department alone of Leonardo's activities the time for several addresses.

We find illustrations and some text notes for flying machines with two and four wings, operated by one or more persons working together or in relays, using the arms and legs or both with the head and neck operating the steering gear or tail with the operator lying prone or standing vertically and with and without spring motors as the main or auxiliary propelling power.

We also find interesting sketches and a notable description of an altogether novel type of screw flying machine—the helicopter—which permits an almost vertical ascent, and a sketch, the first known appearance, of a parachute with descriptive details. His remarkable codex or " Treatise on the flight of birds " is full of the most accurate and careful observations on bird flight, with discussions and experiments on the sustaining power of the air, and the part which the adjustment of wings and their flexing, the adjustable tails and the various kinds and shapes of feathers take in the operations of gliding, soaring, balancing, rising, and

alighting before and against the wind. The sketches of the position of the body wings and tails of birds and insects in flight and their successive positions and warping of the wings show a keenness and accuracy of observation all the more remarkable in the absence of that most efficient modern aid to similar studies—the motion picture camera.

In the Codice Atlantico Fol 314r and the detail appearing on Fol 308r we find two remarkable sketches of the general plan and details of wing mechanisms of a real aeroplane, the



Flying machine wings.

wings operated by a powerful spring motor of which the construction appears clearly indicated with its bow springs, pulleys, countershaft, and even a speed regulator in the form of a fly-ball governor. It would appear that the operator was to stand vertically between the two main uprights rising from the horizontal platform where, in the small sketch assigned to the motor, clearly appear the words, written backwards of course—*Fundamento del Moto*—foundation of the motor.

Leonardo's pioneer work in the field of aviation would alone entitle him to the highest place as a scientist and engineer, for the science, skill and ingenuity he displayed in his endeavor to solve

one of the great problems of the ages, artificial flight, even though he may have achieved no practical results. The record of his work in this field lay dormant and unappreciated for nearly four hundred years, during which the only substantial progress made towards its solution is synthetized in the expression "Lighter than air machines." The importance of these marvelous records is not recognized by students of aviation problems even to-day, although emphasized by students of Leonardo like McCurdy, Beltrami, and others, and will only reach fruition when attention becomes again concentrated on human flight unaided by external power.

One or two quotations, literally translated, may here be of interest:

"One can exert as great power (pressure) with a body (wing) against the air as the air can exert against a similar body (wing).

You observe that wings swung against the air enables the heavy Eagle to float on the thin air of the mountains as he sails into the blue empyrean; as you observe also the air sweeping over the sea against the distended sails, drives forward the heavy ships, pushing back the air from the sails.

You can see therefore from these facts that man with his great artificial wings as he exerts his power against the air and overcomes its resistance can use this resistance as a lever and soar into the air." Ms CA Fol 372b; 1158b

"A bird is an instrument operating according to mathematical laws, this instrument it is within the power of man to be able to imitate with all of its motions but not relatively with so much power; it is lacking only in the power of balancing; therefore it can be said that such an instrument made for man lacks only the soul (will power) of the bird, for which it is necessary to substitute the soul (will power) of the man. This will power will be better (more promptly) obeyed by the individual members in the case of the bird, than by the will of the man which is separated from them and especially in the movements of almost imperceptible balancing, but as we can see the bird provide for the many evident varieties of movement, we can by that experience judge that the most evident motions can be understood by man and that he can largely provide against the destruction of that flying machine of which he has made himself the soul and the motive power." Ms 161ra

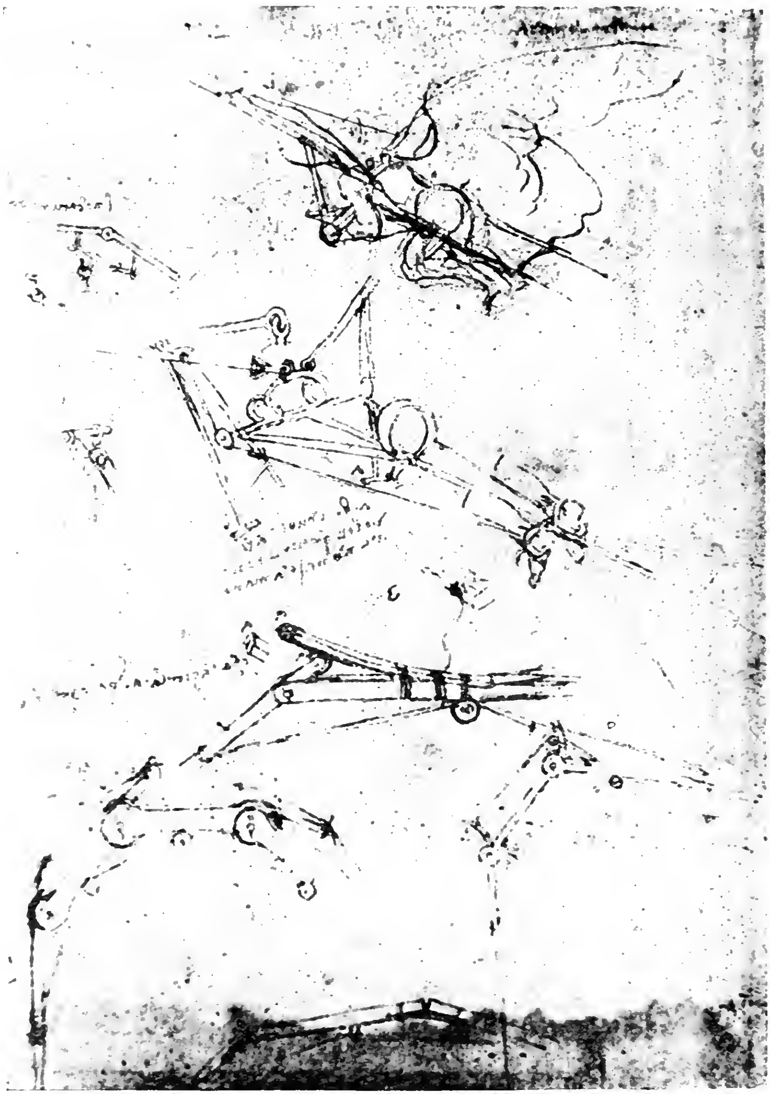
"Construct to-morrow figures (models) of pasteboard of various forms and make them to descend in the air by dropping them from a bridge; and then draw the curves and the motions which the fall of each makes in various parts of its descent."

"If a man has a canopy of water-proof canvas, that is 24 feet on each side and 24 feet high, he can throw himself from any great height without damage to himself." (Parachute) Ms CA Fol 381va

"Try which is greater in its effect, the weight of a man or the push of his legs." Ms Codice Sul Volo Degli Uccelli 17 [16] r

"I have divided the Treatise on Birds into four books: of which the first

treats of their flight by beating their wings; the second of flight without beating the wings and with the help of the wind (soaring); the third of flight in general,



Flying machine and details of construction.

such as that of birds, bats, fishes, animals and insects; the last of the mechanism of this movement." Ms K Fol 3r

"When the bird lowers one of its wings necessity constrains it instantly to extend it, for if it did not do so it would turn right over." Ms K Fol 4v "That part of the air which is the nearest to the wing which presses on it will have the greatest density." Ms K Fol 7r

"In testing flying machines do not fly too near the ground, for if you fall you will not have time to right your machine before hitting the ground." Ms Codice Sul Volo Degli Uccelli Fol 7v

"The imperceptible fluttering of the wings without any actual strokes keeps the bird poised and motionless amid the moving air." Ms CA Fol 308rb.

And so we could continue and fill a whole volume with quotations, but we cannot resist the temptation to add just one more observation which would seem to afford a definite indication that he must have actually flown, for otherwise he could hardly have been aware of an important observation when he says that the movement of the artificial bird should be "above the clouds in order that the wings be not damaged and that the danger from sudden gusts of wind be avoided, as in valleys there is always a gathering of the winds and of whirls and eddies," Ms Codice Sul Volo Degli Uccelli Fol 7v. This is the now well-known phenomena of air ridges and "air holes," a comparatively recent rediscovery as a result of the practical development of the aeroplane.

We have no positive knowledge that Leonardo did actually accomplish any flights, although there is some evidence that he did make some attempts, and like many others after him, was exposed to ridicule for it. We have an early reference in a contemporary work by Gerolamo Cardano (1501–1576) "De Subtilitate," in which, referring to "The excellent arts which are hidden" he says in reference to artificial flight: "It has turned out badly for the two who have recently made a trial of it. Leonardo da Vinci, of whom I have spoken, has attempted to fly but he was not successful; he is a great painter."

In one of his notes, Ms Codice Sul Volo Degli Uccelli Fol 18v, the great master says: "The first flight of the Big Bird will take place from the lofty Swan Hill (near Florence), and the universe will be filled with its praises and the nest whence it sprang will be filled with eternal glory."

CONCLUSION.

Jean Paul Richter in his two classical volumes on Leonardo da Vinci, says:

"It is due to nothing but a fortuitous succession of unfortunate circumstances that we should not long since have known Leonardo not merely as a

Helicopter.

painter, but as an author, a philosopher and a naturalist. There can be no doubt that in more than one department his principles and discoveries were infinitely

more in accord with the teachings of modern science than with the views of his contemporaries.

"For this reason his extraordinary gifts and merits are far more likely to be appreciated in our own time than they could have been during the preceding centuries. He has been unjustly accused of having squandered his powers, by beginning a variety of studies and then, having hardly begun throwing them aside. The truth is that the labors of three centuries have hardly sufficed for the elucidation of some of the problems which occupied his mighty mind."

We do not know to-day how many of Leonardo da Vinci's sketches and drawings were actually original designs or inventions, or how many were merely sketches to aid his memory of things he had seen. We do know that some small portion of the material referred to by Leonardo was not original with him, as he has often specifically mentioned that this or that device or idea was previously used by some one else or in some other country.

It would appear to us, however, from a brief study of the manuscripts from an engineering standpoint, that so many of the sketches contain detailed calculations of weights, power required, costs, etc., and so many others contain practical hints, which are really shop instructions for construction and operation, that they could not have been the result of mere observation of apparatus constructed by others, but must have been the result of practical experiment and experience with actual apparatus under working conditions, supporting the contention that a large part of the sketches are original designs and represent machines, apparatus and structures actually carried out by him or under his immediate direction.

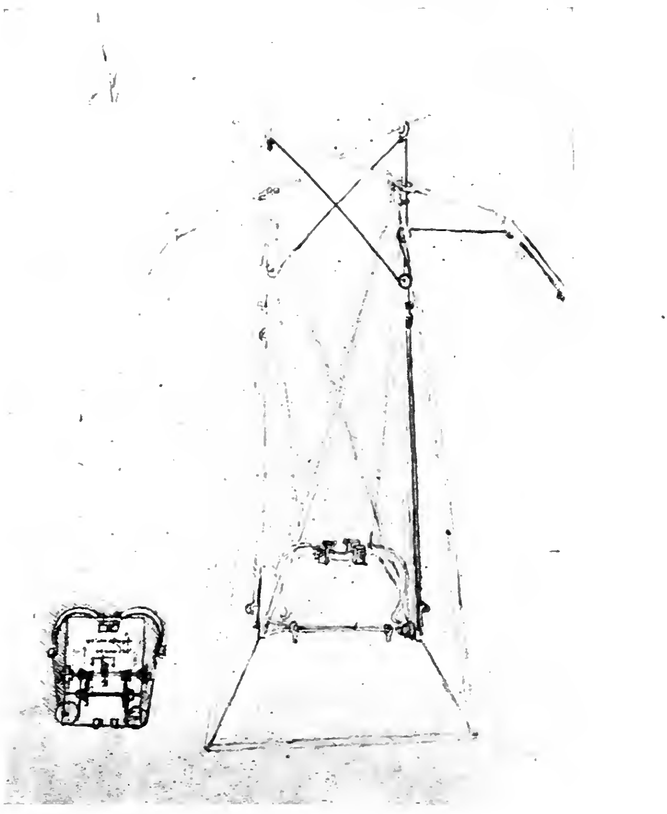
We must also recognize in Leonardo the real founder of scientific prose writing in Italian, his composition being based on the constant and well-defined use of words and terms, casting aside the involved redundant and pedantic style affected by many of his contemporaries.

The speaker has perhaps exceeded proper limits in the insertion of extended quotations, but it was felt that the best insight into Leonardo's personality and mental processes could perhaps be obtained by giving actual quotations from his notes translated as literally as possible.

While many of these notes have been translated directly from the facsimile manuscripts, for many others and for quotations and translations the speaker is indebted to the classical work of Dr.

J. P. Richter and also to the works of Baratta, Beltrami, Beck, De Toni, Duhem, Favaro, Feldhaus, Grothe, Herzfeld, Libri, Müntz, Ronna, Seailles, Seidlitz, Solmi, Venturi, Uzielli, and other foreign authorities, Klebs and Sarton, from this country, and to that excellent work by Edward McCurdy, entitled: "The Note Books of Leonardo da Vinci."

It has not been possible, in the necessarily condensed form of



Flying machine, true aeroplane, motor operated.

this address, to more than give a very general outline, a mere sketch, of the immense field of thought, of research, and of constructive detail over which the activities of this extraordinary genius extended, involving, as it does, Natural Philosophy, Literature, Physics, Mathematics, Geometry, Geology, Botany, Chemistry, Biology, Anatomy and Physiology, the Plastic and Graphic

Arts, Civil, Military, Mechanical and Hydraulic Engineering, and last, but not least of all, Aviation.

I venture the hope, however, that I may have succeeded in exciting your interest and awakening your desire to learn more of Leonardo's work, and I should feel quite happy if I could succeed in reclaiming for this wonderful man, in your estimation, his rightful place in the pantheon of the world's greatest men, not only as a great artist and painter, but as a greater Natural Philosopher and Engineer!

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(Prepared by J. W. L.)

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		Abbreviations.
Library of the Institute de France....	Paris	A to M. Ash I-II.
Ambrosian Library	Milan	Codice Atlantico—C.A.
South Kensington Museum, Forster Library	London	S.K.M.—I_1, I_2, II_1, II_2 III.
British Museum	London	B.M.
Royal Library, Windsor Castle	Windsor	W.A. I-IV. W.P., W.M., W.L., W.H., W.
Holkham Hall, Library of Lord Leicester		Leic.
Library of Prince Trivulzio	Milan	Tr.
Museum of Uffizi	Florence	F.U.
Academy	Venice	V.
Royal Library	Turin	Trn. or Mz.

and miscellaneous scattered sheets.

ORIGINAL ABSTRACTS GROUPED INTO TREATISES OR SUBJECTS.

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THERMAL, ELECTRICAL AND MAGNETIC PROPERTIES OF ALLOYS.*

BY

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INTRODUCTION.

THE physical properties of alloys including hardness, conductivity for heat and electricity, thermoelectric power, magnetic susceptibility, rate of change of resistance with the temperature, etc., are intimately connected with the constitution of the alloys. In the absence of intermetallic compounds the physical properties are in general continuous functions of the composition for any given series of alloys. The physical property may be a linear function of the concentration as is ordinarily the case in conglomerates or it may pass through a maximum or a minimum as in alloys formed of metals which are mutually soluble in each other in all proportions. Discontinuities may occur in cases of limited solubility in the solid state and the curve which represents the variation of the physical property with the composition then shows an abrupt change in direction at the concentration at which one metal ceases to be soluble in the other. In case the metals entering into the alloys form one or more intermetallic compounds the alloys will have a new set of physical properties at the point at which the concentration of the compound is a maximum.

For the purposes of this study of the relation between the thermal, electrical and magnetic properties of alloys and their constitution alloys may be divided into five groups.

I. The two components are not soluble in each other and form no chemical compounds with each other. A metallographic study shows that the alloys in this case are mechanical mixtures of the two components. The lead-cadmium series is an example of this type of alloys. In such alloys the physical property is usually a linear function of the concentration of one of the components. For example, the electrical conductivity of a series of such conglomerates is represented by Curve I of Fig. 1.

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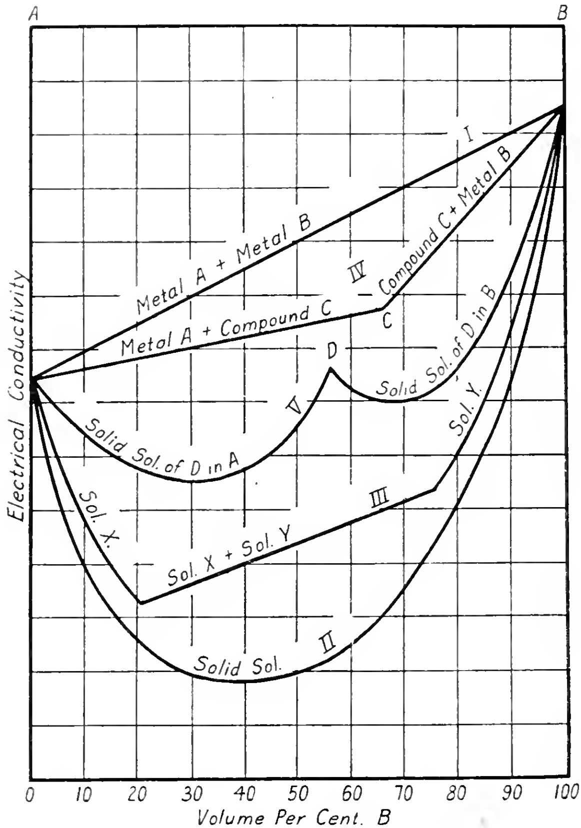
* Communicated by the Author.

II. The two components are soluble in each other in all proportions, *i.e.*, they form by varying the concentration of one of the components an unbroken series of mixed crystals. Alloys of palladium with silver or nickel with copper belong to this group. A curve representing the physical property as a function of the con-

FIG. 1.



centration of one of the components is characterized by a pronounced maximum or minimum. The electrical conductivity when plotted as a function of the concentration of one of the components gives in this case a curve of the form of Curve II of Fig. 1.

III. Each of the components is soluble in the other to a lim-

ited extent. The alloys of this series will then consist of three parts, solid solutions of the first component in the second, solid solutions of the second component in the first and mechanical mixtures of saturated solutions of the first component in the second with saturated solutions of the second component in the first. A typical curve for such a property as the electrical conductivity of alloys of this group is represented in Curve III of Fig. 1. It consists of three parts, a central portion which is linear where there is a mechanical mixture of one saturated solution in another and on either side of this a portion which is similar to the initial and final parts of Curve II.

IV. The two metals *A* and *B* form a single compound *C* (Curve IV, Fig. 1) and this compound forms mechanical mixtures both with *A* and *B*. The curve representing the physical property consists of two straight lines intersecting at *C*.

V. The components form one or more intermetallic compounds. Bismuth-tellurium alloys furnish an example of this group. In this case the curves, showing the physical properties as a function of the concentration of one of the components, may assume a variety of forms according to the nature of the intermetallic compound. If the compound happens to form solid solutions with both of the components in the alloys the curve will take the form of Curve V of Fig. 1. In that case a compound *D* was formed which formed solid solutions with both *A* and *B*.

PHYSICAL QUANTITIES AND UNITS.

The specific resistance has been taken to mean the resistance in ohms or in microöhms of a wire one centimetre in cross section and one centimetre in length. The electrical conductivity is understood to be the reciprocal of the specific resistance, and it has been expressed as the reciprocal of ohms for which the term mho has been used.

The temperature coefficient of the resistance has been considered to be the rate of change of the resistance per ohm per degree Centigrade.

By the thermal conductivity is understood the quantity of heat in calories which will flow in one second through an area of one square centimetre when the temperature gradient is one degree Centigrade per centimetre.

The thermoelectric power has been measured against lead except in a few cases where it has been measured against platinum. These exceptions are clearly indicated on the figures. The thermoelectric power has been expressed as the number of microvolts for a difference of one degree Centigrade between the junctions. For the rate of variation of the thermoelectric power with the temperature the Centigrade scale has also been used.

The Thomson coefficient, which is a measure of the heat absorbed or evolved in excess of the Joulean heat by a current of electricity flowing along an unequally heated conductor, has been measured in ergs. It gives the amount of heat in ergs which is absorbed or generated in excess of Joulean heat by a current of one absolute unit flowing through a conductor in which there is a temperature gradient of one degree Centigrade per centimetre.

In the Hall constant which is a measure of the rotation of the equipotential lines under the action of a transverse magnetic field, the electric current, the transverse difference of potential and the magnetic field have been measured in absolute units and the thickness of the plate in centimetres. This constant is defined by the equation,

$$E = R\frac{Hi}{d}$$

where E = the transverse electromotive force produced by the magnetic action.

H = the intensity of the magnetic field.
i = the current in the plate.
d = the thickness of the plate.
R = the Hall constant.

For paramagnetic and diamagnetic substances the relation between the intensity of magnetization and the magnetic field which produces it may be expressed by the equation,

$$I = kH.$$

where H = the magnetic field in gausses.
k = the magnetic susceptibility per unit volume.

Sometimes the magnetic susceptibility per unit mass is used. In such a case it is called the specific magnetic susceptibility and is defined by the relation,

$$\chi = \frac{k}{\rho},$$

where ρ = density of the substitute.

To get a measure of the elastic properties of the alloys it has been necessary to accept the data on these properties in a variety of forms. In some cases the hardness on Brinell's scale has been used; in others the pressure necessary to cause the metal or alloy to flow, and in others the tensible strength. There is no simple way of passing from one of these kinds of data to the other. They all give some measure of the cohesive forces with which the metals and alloys are held together, and that was all that was needed in this connection.

Above the freezing point curve an attempt has been made to indicate the manner in which the metals mix to form the alloys (see Guertler, "Metallographie"). Where the alloys are mechanical mixtures for all concentrations of the constituents, this fact has been indicated by placing a plus sign between the chemical symbols of the constituents. For example $Zn + Sn$ means that tin and zinc are mechanical mixtures in all proportions. In case the metals A and B form an unbroken series of solid solutions, this has been indicated by writing *Sol–A–B* above the freezing point curve. If one metal A is soluble to a limited extent in the other B – a saturated solid solution of A in B has been denoted by $\bar{I}$ and a saturated solid solution of B in A by $\bar{II}$. Where these saturated solid solutions then mix mechanically to form the remainder of the alloys, this fact has been indicated by $I + II$. For example in the case of the copper-silver series, the numerals above the freezing point curve indicated that copper dissolves about 3 per cent. silver, and that silver dissolves about 5 per cent. copper. These saturated solid solutions then mix mechanically to form the remainder of the alloys.

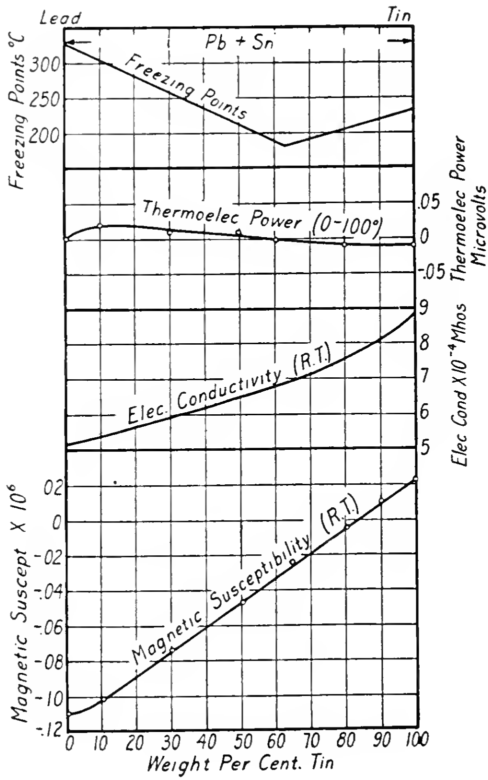
The temperature at which the observations were made or the interval of temperature over which they were made has been given on the curves as far as possible. In a number of cases the temperatures at which the observations were made were not clearly given by the observer. This is especially true for observations made in the neighborhood of room temperature. Where the observations were made near room temperature the letters (*R.T.*) have been written on the curves to indicate that fact.

METALS INSOLUBLE IN EACH OTHER.

Lead-Tin.

The freezing point curve by Degens [1] (Fig. 2) for lead-tin alloys shows a eutectic but no evidence of compounds. Tin seems to be somewhat soluble in lead and possibly lead is to a small

FIG. 2.



degree soluble in tin. Between low and high concentrations of tin the alloys are heterogeneous mixtures of the crystalline phases.

The electrical conductivities as measured by Roberts [2] give nearly a straight line as is to be expected from the fact that the alloys are heterogeneous mixtures of the components. The thermo-

[1] Degens: *Zeit. anorg. Chem.*, 63, 207, 1909.

[2] Roberts: *Phil. Mag.* (5), 8, 57, 1879.

electric powers have been determined by Rudolfi [3] and his results plotted in Fig. 2. The diamagnetic susceptibility by Honda [4] gives a curve which is nearly a straight line beginning with the value in lead and ending with the value in tin. In the alloys rich in lead (between 0 and 10 per cent. tin) where a solid solution is formed, the susceptibility decreases somewhat less rapidly than the linear relation requires. The linear relation between susceptibility and concentration follows at once from the fact that except for low and possibly high concentrations of tin the alloys are mechanical mixtures of the components.

Tin-Zinc.

The two branches of the freezing point curve (Fig. 3) by Heycock and Neville [5] meet at the eutectic. The changes in curvature are all gradual and there is no evidence of compounds. The alloys consist of heterogeneous mixtures of tin and zinc.

Measurements of the electrical conductivity have been made by Matthiessen,[6] Vogt,[7] Harris and Le Chatelier.[8] More recently Schulze [9] has studied both the thermal and the electrical conductivities. His observations have been plotted in Fig. 3. The temperature coefficient is from the work of Matthiessen and Vogt. Besides the observations of Rudolfi [3] on the thermoelectric heights there are earlier observations by Rollmann and Battelli.[10] The observations of Rudolfi have been used for the curve of thermoelective forces. Except for minor variations these curves are essentially linear and typical of alloys which are formed by mechanically mixing the constituents.

Bismuth-Cadmium.

The freezing point curve (Fig. 4) by Stoffel [11] is composed of two branches meeting at the eutectic for which the temperature

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[3] Rudolfi: *Zeit. anorg. Chem.*, **67**, 65, 1910.

[4] Honda: *Sci. Rept. Tokio Univ.*, **2**, 11, 1913.

[5] Heycock and Neville: *Jour. Chem. Soc.*, **71**, 383, 1897.

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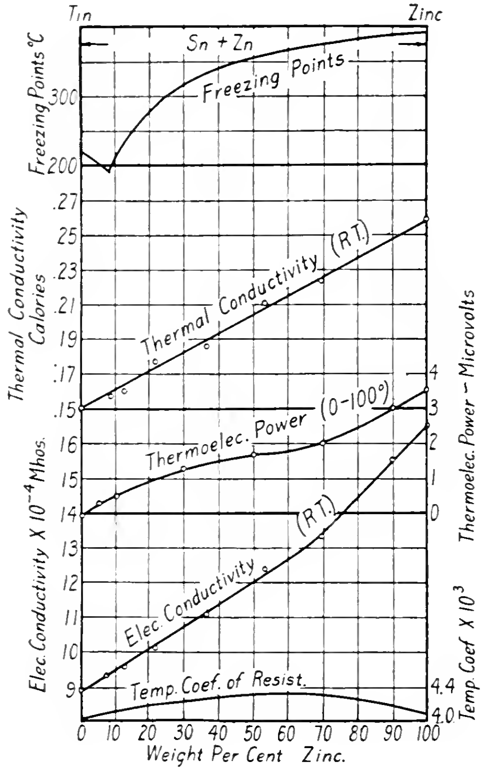
[10] Battelli: *Atti. R. Inst. Ver.* (6), **5**, 1886–7.

[11] Stoffel: *Zeir. anorg. Chem.*, **53**, 137, 1907.

is 148° C. In all proportions the alloys are heterogeneous mixtures of bismuth and cadmium.

The thermoelectric powers by Rudolfi [12] and the magnetic susceptibility by Guesatto and Binghinnoto [13] give curves which have the form to be expected in heterogeneous mixtures. Each of these curves by their steepness where the concentration of bismuth is

FIG. 3.



large suggests that cadmium is to a limited extent soluble in bismuth. There is some evidence from the study of the homogeneity of these alloys that cadmium may be soluble in bismuth up to about 1 per cent.

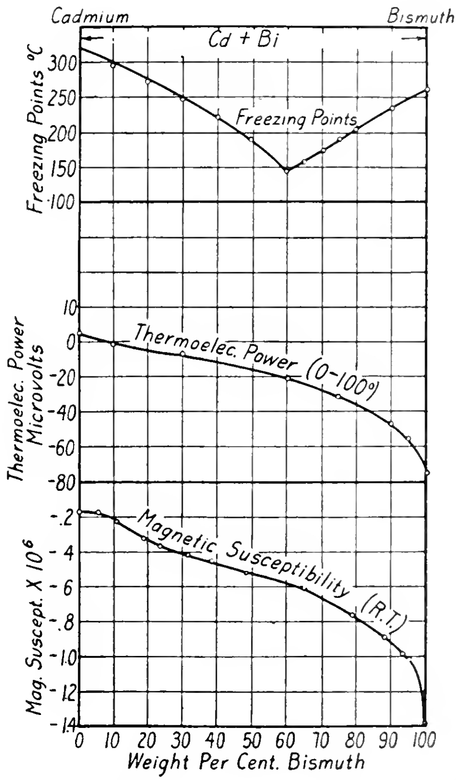
[12] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.

[13] Guesatto and Binghinnoto: *Inst. Ven.*, 69, 1382.

Cadmium-Tin.

The equilibrium diagram by Lorentz and Plumbridge [14] shows that the freezing point curve (Fig. 5) consists of two branches meeting at a eutectic when the alloy contains about 28 per cent. cadmium. These alloys are heterogeneous mixtures in all proportions.

FIG. 4.



The electrical conductivity curve by Matthiessen and Vogt [15] is a straight line. The curve giving the thermoelectric power as a function of the concentration is also a straight line. Besides these observations by Rudolfi [12] there are some earlier observations by Battelli.[16] Both of these curves are characteristic of alloys formed by mechanical mixtures of the constituents. Concerning the other

[14] Lorentz and Plumbridge: *Zeit. anorg. Chem.*, 83, 237, 1913.

[15] Matthessien: *Pogg. Ann.*, 110, 206, 1860.

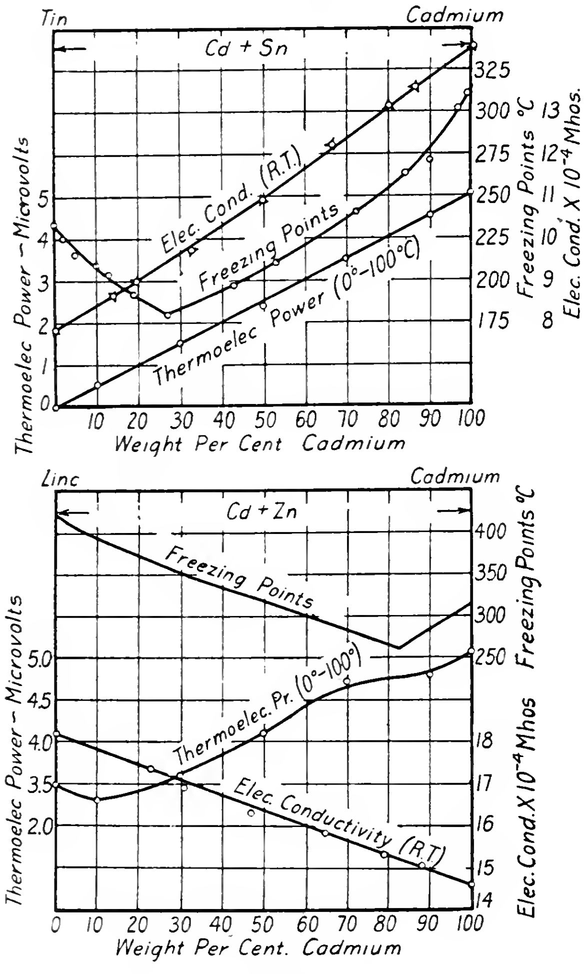
[16] Battelli.: *Mem. di Torino* (2), 36, 31, 1884.

thermal, electrical and magnetic properties of these alloys, no observations seem to be available.

Cadmium-Zinc.

The freezing point curve for cadmium-zinc alloys by Lorentz and Plumbridge [17] (Fig. 5) consists of two branches meeting at the

FIG. 5.



eutectic for which the temperature is 270° C. The alloys are mechanical mixtures of zinc and cadmium.

[17] Lorentz and Plumbridge: *Zeit. anorg. Chem.*, 83, 236, 1913.

The electrical conductivities at room temperature have been measured by Matthiessen [18] and also by Vincentini. The curve showing the electrical conductivity as a function of the concentration of one of the constituents come out to be a straight line, as it should for this type of alloys. Battelli [19] has made a study of the thermoelectromotive forces of these alloys and a later investigation was made by Rudolfi.[20] The average values of the thermoelectric powers as determined by Rudolfi have been plotted on the curve in Fig. 5. This curve departs somewhat from a straight line and suggests by its minimum for low concentrations of cadmium that cadmium may be soluble to a limited extent in zinc.

Aluminium-Tin.

The freezing point curves of Gautier [21] and Gwyer [22] for this series of alloys differ by the fact that the freezing point curve of Gautier has a maximum corresponding to the compound AlSn and the curve by Gwyer shows no such maximum. The curve by Gwyer seems to be preferred and it has been reproduced in Fig. 6. According to Gwyer, there seems to be a eutectic which coincides nearly with the melting point of tin. Except for the possibility of slight solubility in each other these metals form alloys which are mechanical mixtures.

Besides the observations of Broniewski [23] on the electrical properties of these alloys there are available some observations by Pecheux on their thermoelectromotive force. The data given by Broniewski have been used for the curves plotted in Fig. 6. These curves in agreement with the freezing point curve lead to the conclusion that these metals do not form definite compounds and are characterized by dilute solid solution of tin in aluminium and a mixture of this solution with tin.

Aluminium-Bismuth.

Gwyer [24] found by thermal analysis that the solubility of aluminium in bismuth is about 2 per cent. and that of bismuth in

[18] Matthiessen: *Pogg. Ann.*, 110, 28, 1860.

[19] Battelli: *Atti. R. Inst. Veneto* (6) 5, 1148, 1886.

[20] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.

[21] Gautier: *C. R.*, 123, 109, 1896.

[22] Gwyer: *Zeit. anorg. Chem.*, 49, 315, 1906.

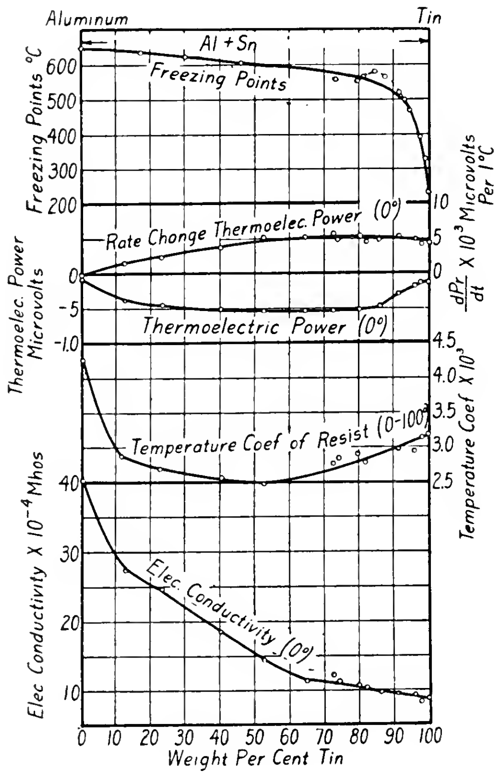
[23] Broniewski: *Ann. de Phys. et Chem.* (8), 25, 63, 1912.

[24] Gwyer: *Zeit. anorg. Chem.*, 49, 316, 1906.

aluminium is about 4 per cent. at 650° C., but inappreciable at the melting point of bismuth. The alloys may, therefore, be regarded as mechanical mixtures of aluminium and bismuth. The freezing point curve of Fig. 7 is by Gwyer.

Some work has been done by Pecheux [25] on the thermoelectromotive forces in these alloys. They were more fully studied by

FIG. 6.



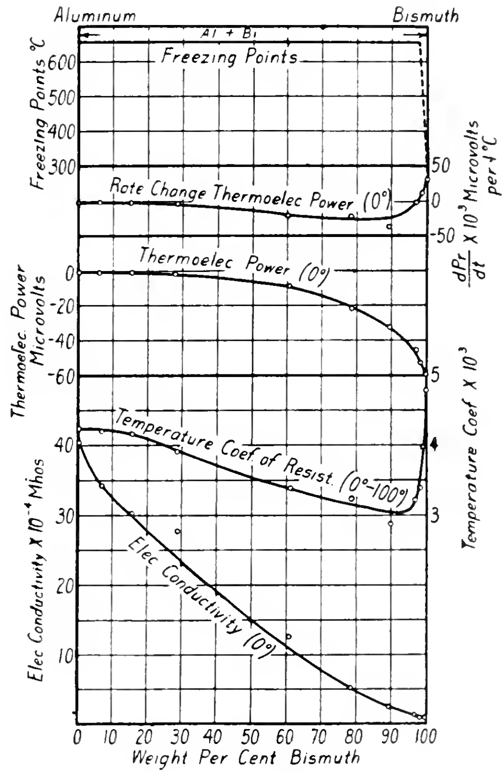
Broniewski [26] from whose observations the curves in Fig. 7 have been taken. Except for a slight minimum where the concentration of aluminium is small the curve for electrical conductivities is nearly a straight line, as it should be for alloys formed by metals which are mechanically mixed. The curve for the temperature

[25] Pecheux: *C. R.*, 138, 1501, 1904.

[26] Broniewski: *Ann. de Phys. et Chem.* (8), 25, 66, 1912.

coefficient of the resistance has a minimum at about 95 per cent. bismuth. This together with the slight minimum in the electrical conductivity curve indicates the formation of a solid solution of aluminium in bismuth. Since these minima are more pronounced

FIG. 7.



in the unannealed than in the annealed specimens the solid solution is probably decomposed by annealing.

METALS COMPLETELY SOLUBLE IN EACH OTHER.

Indium-Lead.

Lead and indium form an isomorphous mixture in all proportions. The freezing point curve (Fig. 8) by Kurnakow and Puschin[27] is a continuous curve through the melting points of lead and indium.

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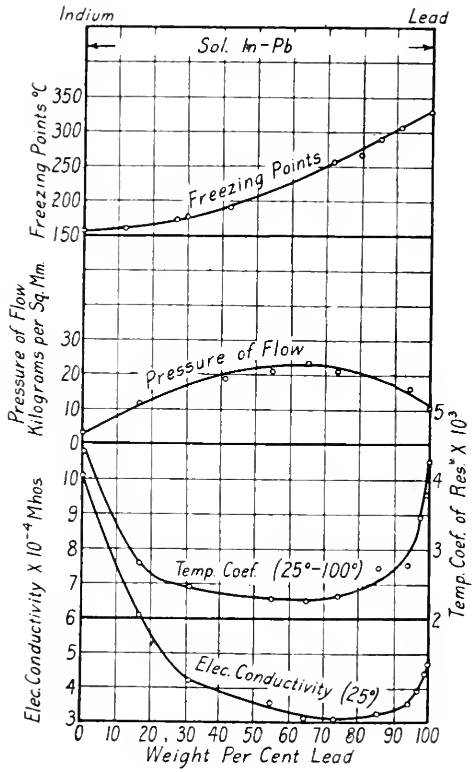
[27] Kurnakow and Puschin: *Zeit. anorg. Chem.*, 52, 430, 1907.

The electrical conductivity and the temperature coefficient have been measured by Kurnakow and Zemczuzny.[28] These authors have also determined the pressure necessary to cause these alloys to flow. All of the curves representing these physical quantities as

FIG. 8.



functions of the concentration are typical of alloys in which the constituents form a continuous series of mixed crystals. The pressure necessary to produce flow has a maximum value where the electrical conductivity and the temperature coefficient of the resistance have minimum values. This indicates that the electrical properties are in part at least determined by the elastic properties.

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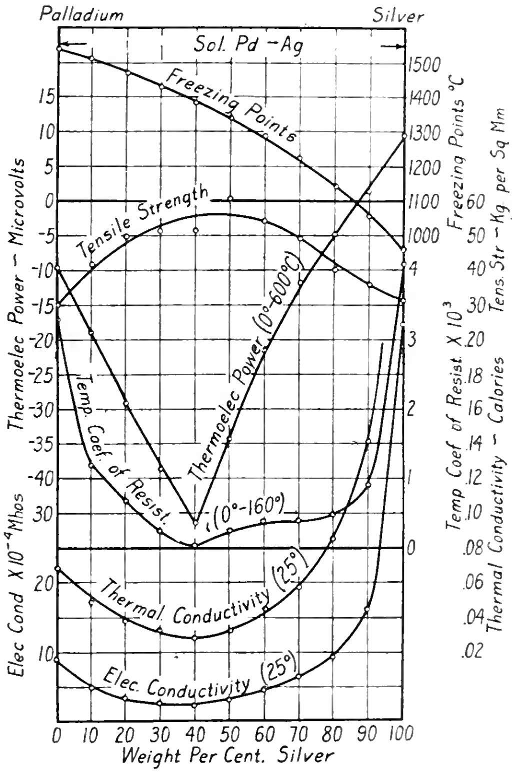
[28] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 64, 149, 1909.

Palladium-Silver.

The freezing point curve of these alloys (Fig. 9) is plotted from the data of Ruer.[29] The metals form solid solutions in all proportions.

The electrical and thermal conductivities have been determined by Schulze.[30] He used the same specimens which had been used by Giebel [31] for the study of the electrical conductivity, the tem-

FIG. 9.

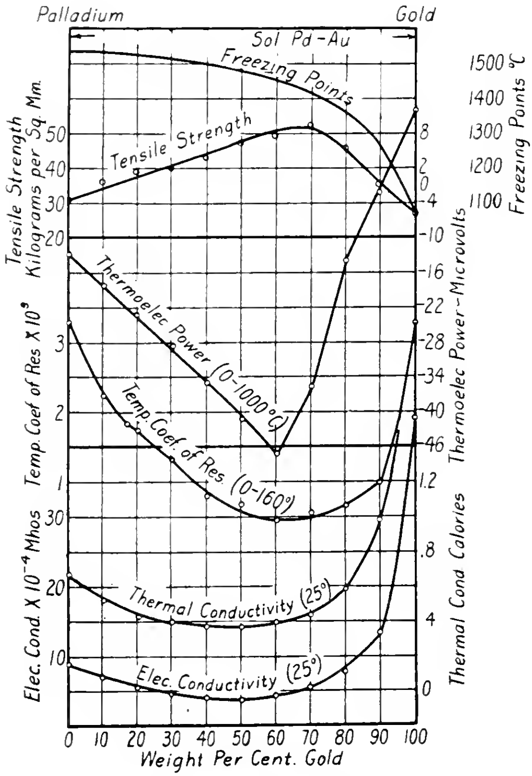


perature coefficient of the resistance, the thermoelectric heights and the tensile strength. All of these curves except possibly the one for thermoelectric heights are characteristic of metals which

[29] Ruer: *Zeit. anorg. Chem.*, **51**, 315, 1906.
[30] Schulze: *Physikal Zeitschr.*, **12**, 1029, 1911.
[31] Giebel: *Zeit. anorg. Chem.*, **70**, 240, 1911.

form a continuous series of mixed crystals. The elastic properties as represented by the tensible strength of these alloys have a maximum where the electrical conductivity, the thermal conductivity, the thermoelectric power and the temperature coefficient of the resistance have minimum values.

FIG. 10.



Palladium-Gold.

From the freezing point curve of Ruer [2] (Fig. 10) it is seen that the freezing point of these alloys changes gradually from the melting point of palladium to the melting point of gold. The metals form an unbroken series of mixed crystals.

The electrical and thermal conductivities have been measured by Schulze [3] and the thermoelectric powers, the temperature coefficient and the tensile strengths by Giebel [32] who also measured the

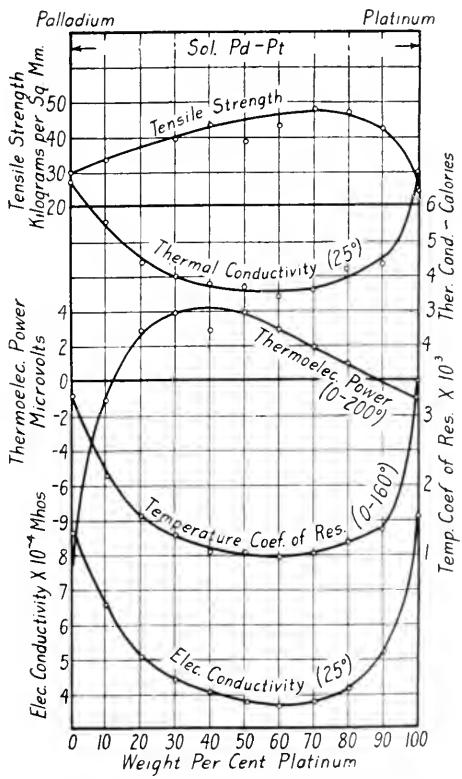
[32] Giebel: *Zeit. anorg. Chem.*, **70**, 240, 1911.

electrical conductivity. All of these observations were made on the same specimens. These curves are all very similar to the corresponding curves for palladium-silver alloys and typical of alloys in which there is an unbroken series of mixed crystals. Here as in other similar cases the elastic properties are related to the electrical and thermal properties.

Palladium-Platinum.

The freezing point curve for this series of alloys does not seem to have been studied. The physical properties (Fig. 11) clearly

FIG. 11.

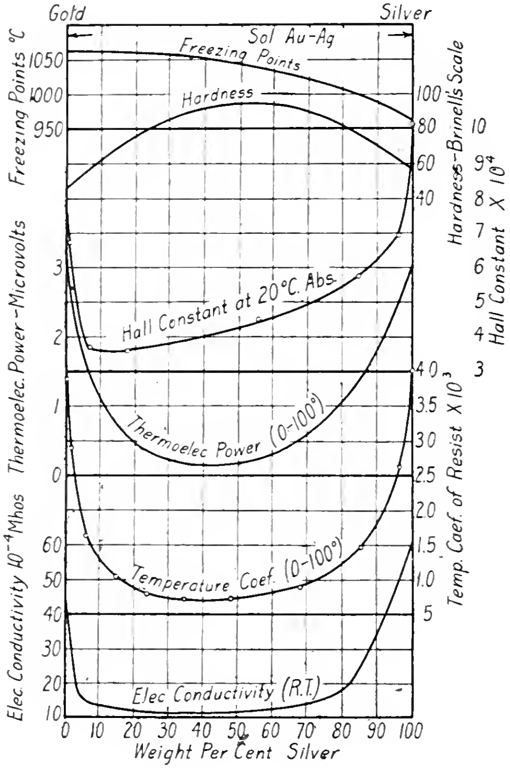


indicate that these metals mix in all proportions forming a continuous series of mixed crystals.

The thermal and electrical conductivities which have been given in Fig. 11 have been taken from the work of Schulze who made

his observations on the same specimens on which Giebel[32] had made observations on the electrical conductivity, the temperature coefficient of the resistance, the thermoelectric power and the tensile strength. There is an evident parallelism between the elec-

FIG. 12.



trical and thermal conductivities. In this series as in the palladium-silver series the curve of tensile strengths has a maximum where the electrical and thermal conductivities have minimum values.

Gold-Silver.

Roberts-Austen and Kirke Rose, confirming the work of Heycock and Neville,[33] showed that gold and silver solidify in the form of an unbroken series of mixed crystals. The freezing point changes continuously from its value in gold to its value in silver.

[33] Heycock and Neville: *Phil. Trans. A.*, **189**, A, 69, 1897.

The curve for the electrical conductivities (Fig. 12) is plotted from the observations of Matthiessen.[34] The average thermoelectric power has been calculated from the data of Rudolfi [35] and the Hall constant from the work of Beckman.[36] The hardness has been measured by Kurnakow.[37] The similarity between the four lower curves in Fig. 12 is very evident. The elastic property has a maximum value where the other properties have minimum values, indicating that the elastic forces in the alloys help to determine the Hall effect as well as the electrical conductivity, the temperature coefficient of the resistance and the thermoelectric powers.

Copper-Gold.

From the observations of Kurnakow and Zemczuzny [38] on the freezing points of copper-gold alloys (Fig. 13) it is found that the freezing point curve runs in a simple way from the melting point of copper to the melting point of gold. It has a minimum where the alloy contains about 25 per cent. copper. These metals form a continuous series of solid solutions.

The electrical conductivity of this series has been studied by Matthiessen [39] and in later times by Kurnakow, Zemczuzny and Zasedatelev [40] from whose observations have been taken both the curve for electrical conductivities and the curve for temperature coefficient of resistance. The hardness which has been measured by Kurnakow and Zemczuzny [41] shows the maximum which is characteristic of a series of solid solutions. The average thermoelectric power as found by Rudolfi [1] has been used for the thermoelectric height curve. Except for the two peaks in the curve for the electrical conductivity and two corresponding peaks in the curve for the temperature coefficient of the resistance, this set of curves is very similar to the set found for alloys of platinum and palladium in which there was a continuous series of solid solutions.

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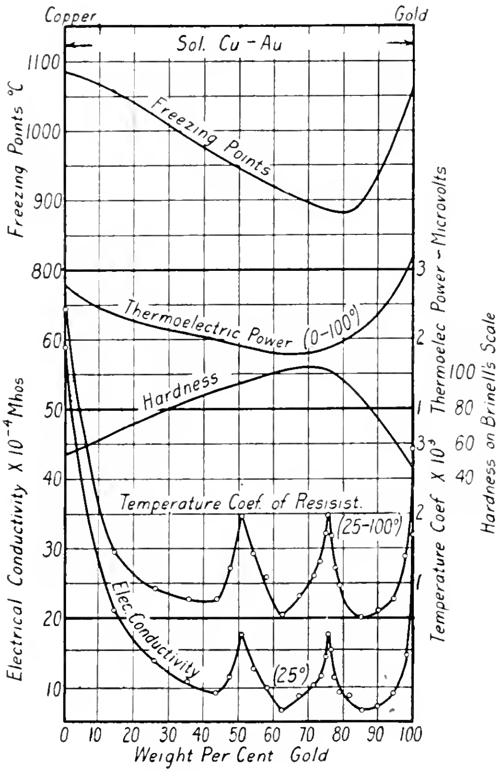
[34] Matthiessen: *Pogg. Ann.*, 110, 190, 1861.
[35] Rudolfi: *Zeit. anorg. Chem.*, 67, 65, 1910.
[36] Beckman: *Com. fr. Phys. Lab. Univ. of Leiden*, 130, 27, 1912.
[37] Kurnakow: *Zeit. anorg. Chem.*, 60, 1, 1908.
[38] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 54, 163, 1907.
[39] Matthiessen: *Pogg. Ann.*, 110, 217, 1860.
[40] Kurnakow, Zemczuzny and Zasedatelev: *J. Inst. of Metals*, 15, 305, 1916.
[41] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 60, 1, 1908.

Potassium-Rubidium.

These metals form isomorphous mixtures in all proportions. The freezing point curve has not been located and it seems to be unknown.

The observations on the electrical conductivity and on the rate of change of the resistance with the temperature (Fig. 14) are

FIG. 13.

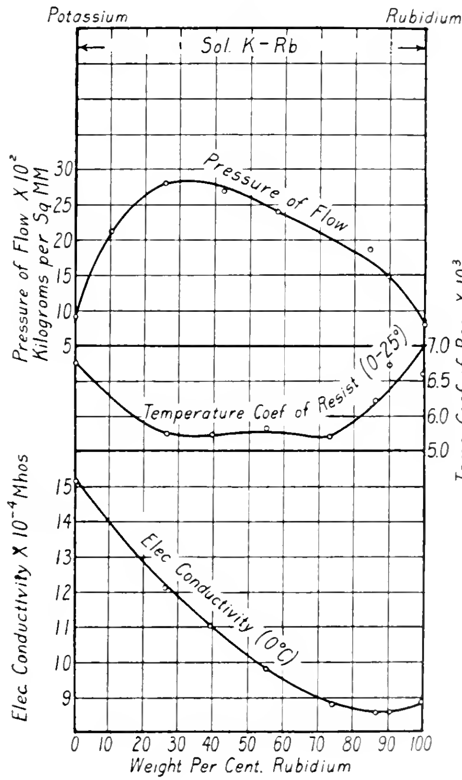


due to Kurnakow and Nikitinsky.[42] They also determined the pressures required to cause the alloys to flow. The electrical conductivity as a function of the concentration of one of the components is represented by a continuous curve with a very slight minimum. This is characteristic of isomorphous mixtures. With rising temperature the minimum is displaced toward rubidium—

[42] Kurnakow and Nikitinsky: *Zeit. anorg. Chem.*, **88**, 151, 1914.

the metal with the least conductivity. The curve for the rate of change of the resistance with the temperature shows the minimum characteristic of this type of alloys. The only difference between these curves and those obtained under similar conditions for most isomorphous mixtures is the smaller decrease in the electrical conductivity which is produced by adding rubidium to potassium. In most cases in which solid solutions are formed this decrease is

FIG. 14.



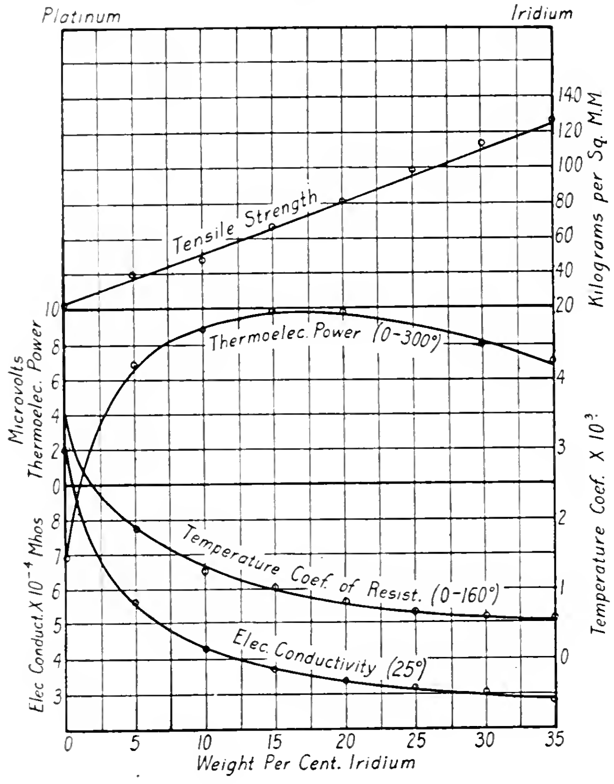
much larger than it is in this case. The elastic properties as measured by the pressure necessary to cause the alloys to flow show the characteristic maximum found in isomorphous mixtures.

Platinum-Iridium.

The equilibrium diagram for this series has not been located. These metals probably form solid solutions.

The electrical conductivity, the temperature coefficient, the thermoelectric power, and the tensile strength have been studied by Giebel [43] for this series of alloys for concentrations of iridium between 0 and 35 per cent. These curves are reproduced in Fig. 15. The tensile strength is a linear function of the concen-

FIG. 15.



tration of iridium over this interval. The thermoelectric power passes through a maximum between 15 and 20 per cent. iridium. The addition of iridium to platinum lowers both the electrical conductivity and the temperature coefficient in the way to be expected on the assumption that the metals form solid solutions.

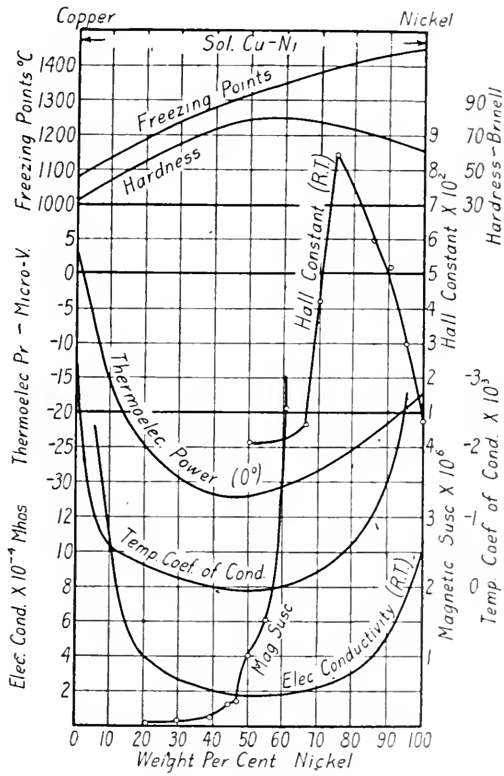
[43] Giebel: *Zeit. anorg. Chem.*, **70**, 247, 1911.

Copper-Nickel.

The freezing point curve for this series of alloys (Fig. 16) is the one worked out by Guertler and Tammann.[44] These metals form an unbroken series of solid solutions.

The electrical conductivity and the temperature coefficient have

FIG. 16.



been measured by Feussner.[45] The curves thus obtained are characteristic of a continuous series of solid solutions. The thermoelectric power by Englisch [46] and the hardness by Kurnakow and Papke [47] also give the type of curve to be expected in alloys which

[44] Guertler and Tammann: *Zeit. anorg. Chem.*, 53, 281, 1907.
[45] Feussner: *Verhand. d. physik Gesel. zu Berlin*, 10, 109, 1891.
[46] Englisch: *Phys. Consts. Soc. Fran. de Phys.*, p. 654, 1893.
[47] Kurnakow and Papke: *Zeit. anorg. Chem.*, 87, 274, 1914.

are solid solutions. The curve of hardness shows a maximum where the curve for the electrical conductivity has a minimum, thus showing that the elastic properties in a measure determine the electrical conductivity and its variation with the temperature. The curve for the magnetic susceptibilities has been taken from the observations of Gans and Fouseca.[48] The Hall constant is by the author.[49] Neither the Hall constants nor the magnetic susceptibilities seem to depend on the concentration in the way to be expected for solid solutions.

Iron-Nickel.

The freezing point curve (Fig. 17) by Guertler and Tammann [50] indicates that iron and nickel form a continuous series of solid solutions. On the freezing point curve as sometimes given there seems to be a change in curvature at the concentration corresponding to the compound Ni_2Fe, from which this compound is sometimes inferred.

The specific heat, the electrical conductivity, the temperature coefficient, the thermal conductivity and the thermoelectric heights have been measured by Ingersoll and others.[51] The flux densities given in Fig. 17 are from the observations of Yensen [52] and were measured for an external magnetic field of 400 gausses. The specific heat is a maximum at the concentration of the possible compound Ni_2Fe. The electrical conductivity, the temperature coefficient and the thermoelectric power have minimum values where the intermetallic compound might be formed. Of all these curves only the one for the thermal conductivities has the general form to be expected in a series of alloys which are an unbroken series of solid solutions. The complexity of the curves in this case is doubtless due to the fact that both nickel and iron are polymorphic.

Magnesium-Cadmium.

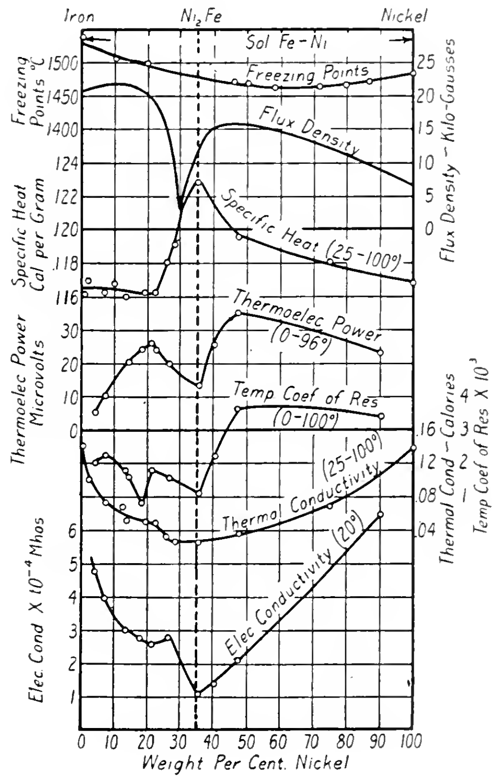
The freezing point curve by Grube [53] has a point of inflection where the concentration corresponds to the compound MgCd.

[48] Gans and Fouseca: *Ann. d. Phys.*, 61, 742, 1920.
[49] Smith: *Phys. Rev., N. S.*, 17, 24, 1921.
[50] Guertler and Tammann: *Zeit. anorg. Chem.*, 45, 205, 1905.
[51] Ingersoll: *Phys. Rev., N. S.*, 16, 85, 1920.
[52] Yensen: *Jour. A. I. E. E.*, 396, 1920.
[53] Grube: *Zeit. anorg. Chem.*, 49, 72, 1906.

This change in curvature is not very evident in the curve as plotted in Fig. 18. According to this equilibrium diagram the alloys are solid solutions of two crystalline phases. About the equilibrium in this series there is still considerable doubt.

The electrical conductivity, the temperature coefficient, and

FIG. 17.

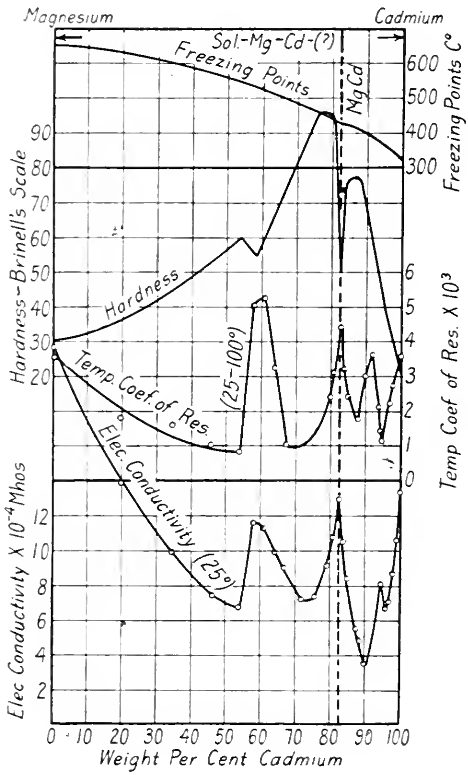


hardness have been measured by Ourazow.[54] On both of these curves the compound MgCd is clearly marked by a cusp. This compound is also indicated on the curve for hardness. On either side of the compound there is a second cusp in the curve for electrical conductivity and for the temperature coefficient. If these cusps were absent the curves would have the normal course

[54] Ourazow: *Zeit. anorg. Chem.*, 73, 31, 1912.

to be expected on the assumption that alloys to the right of the compound are solid solutions of cadmium and the compound MgCd and those to the left of the compound solid solutions of magnesium with the compound MgCd. The thermal analysis is

FIG. 18.



not in agreement with the indications given by the thermal and electrical properties in this case.

METALS WITH LIMITED SOLUBILITY IN EACH OTHER.

Aluminium-Zinc.

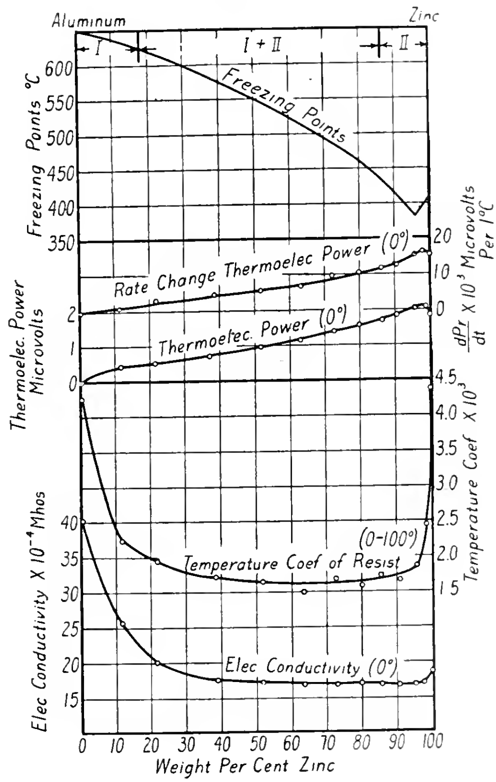
The freezing point curve of aluminium-zinc alloys from Gautier [55] (Fig. 19) is made up of two branches which meet at the temperature of fusion of the eutectic. There are no compounds

[55] Gautier: *Bull. Soc. Encour.* (5), 1, 1293, 1896.

and Shepherd[56] concludes from a micrographic study that aluminium-zinc alloys are formed of two solid solutions and a mechanical mixture of these solid solutions.

Besides the observations of Broniewski[57] on the electrical

FIG. 19.



properties of these alloys there are earlier observations by Battelli[58] and Pecheux.[59] The curves in Fig. 19 have been plotted from the observations of Broniewski. The curves all belong to that group of alloys which are formed from metals which are soluble in each other to a limited extent and in which the solid solutions

[56] Shepherd: *Jour. Phys. Chem.*, **9**, 504, 1905.

[57] Broniewski: *Ann. de Chem. et Phys.* (8), **25**, 1, 1912.

[58] Battelli: *Atti. R. Inst. Veneto.* (6), **5**, 1148, 1886–7.

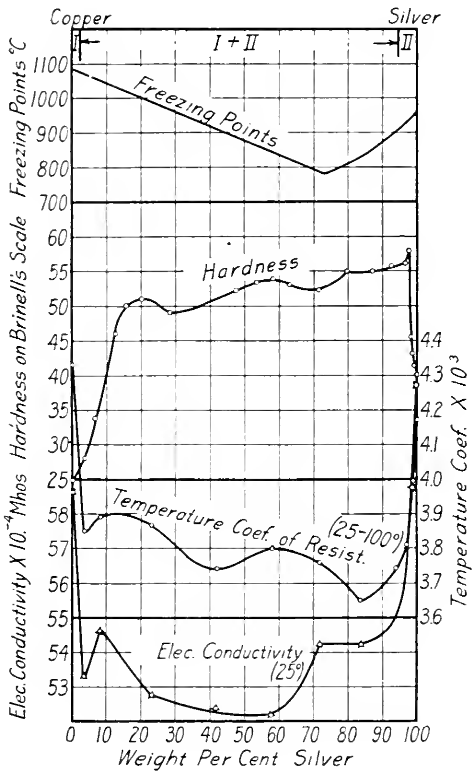
[59] Pecheux: *C. R.*, **138**, 1103, 1904.

thus formed mix with each other mechanically. The central portions of the curves are nearly linear as should be the case for mechanical mixtures.

Copper-Silver.

A thermal analysis of copper-silver alloys has been made by Heycock and Neville.[60] Their results have been confirmed by the

FIG. 20.



work of Friedrick and Leroux and Lepowiski,[61] from whose work the freezing point curve (Fig. 20) is taken. Copper forms a solid solution with silver and silver with copper until the concentration of the copper in one case and silver in the other is about

[60] Heycock and Neville: *Phil. Trans. A.*, **189**, 25, 1897.
[61] Lepowiski: *Zeit. anorg. Chem.*, **59**, 289, 1908.

5 per cent. The remainder of the alloys are heterogeneous mixtures of these saturated solid solutions.

The hardness, the electrical conductivity and the temperature coefficient of this series are due to Kurnakow, Puschin and Semkowsky.[62] Where a solid solution is formed between copper and silver there is a marked lowering of both the electrical conductivity and the temperature coefficient. Hence for high as well as low concentrations of silver these curves are very steep. The central portions of these curves, although somewhat irregular, approach the form to be expected in a region where there is a mechanical mixture of two crystalline phases. There is a marked increase in hardness over the intervals in which solid solutions are formed. The remainder of the hardness curve is such as is to be found where the alloys are mechanical mixtures of two crystalline phases. Except for some irregularities this set of curves clearly belongs to metals which form solid solutions with each other to a limited extent and then these solid solutions mix mechanically to form the remainder of the alloys.

Bismuth-Lead.

The freezing point curve by Kapp and Charpy [63] (Fig. 21) has a eutectic at 56.5 per cent. bismuth. Herold [64] finds that for suitable concentrations lead and bismuth form mixed crystals, but the region over which these solid solutions extend is not clearly defined. The solutions, however, are rather dilute. The remainder of the alloys are mechanical mixtures of two crystalline phases.

The hardness curve indicates by the increase in hardness for low and high concentrations of bismuth the formation of solid solutions at the beginning and end of this series. The remainder of the curve of hardness over the region where the alloys are heterogeneous mixtures is a straight line. The thermal and electrical conductivities by Schulze [65] have minima for alloys containing 4 or 5 per cent. of lead. This as well as the initial drops in these curves for alloys containing from 0 to 15 per cent. bismuth is further evidence for the formation of solid solutions at either end of this series. The thermoelectromotive force which

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[62] Kurnakow, Puschin and Semkowsky: *J. d. russ. phys. Chem.*, **42**, 733, 1910.

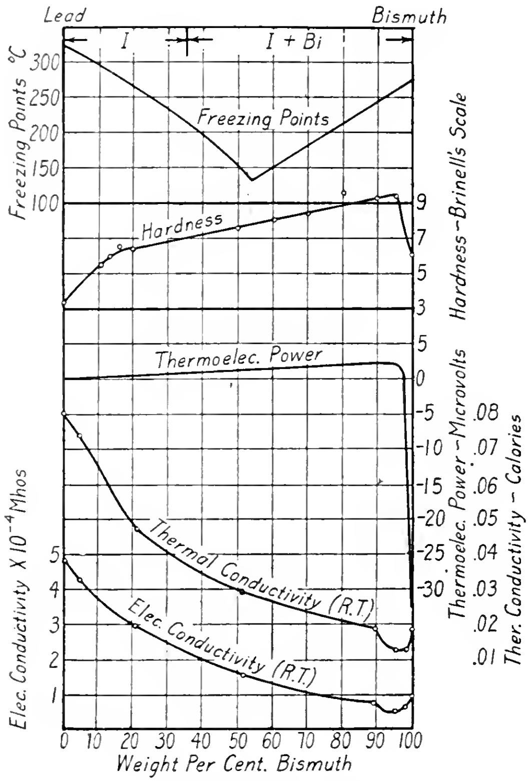
[63] Barlow: *Zeit. anorg. Chem.*, **70**, 183, 1911.

[64] Herold: *Zeit. anorg. Chem.*, **112**, 131, 1920.

[65] Schulze: *Ann. d. Phys.*, **9**, 564, 1902.

has been studied by Battelli [66] shows a rapid decrease for the addition of small quantities of lead to bismuth. The characteristics of this curve in this region are similar to the characteristics of the other curves over this same region.

FIG. 21.



Antimony-Tin.

The freezing point curve by Williams [67] (Fig. 22) consists of three parts. Later study of equilibrium in this system has been made by Konstantinow and Smirnow, LeGris and Loebe. Between 90 and 100 per cent. antimony there is a solid solution of tin in antimony and between 0 and 10 per cent. tin there is a

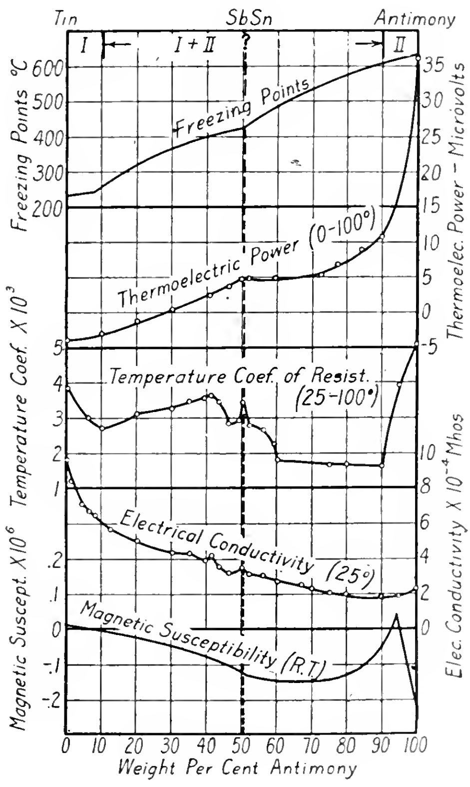
[66] Battelli: *Atti. R. Inst. Veneto* (6), 5, 1148, 1886.

[67] Williams: *Zeit. anorg. Chem.*, 55, 12, 1907.

solid solution of antimony in tin. When the metals are present in equal concentrations a new crystalline phase is formed, probably the intermetallic compound SnSb. Those alloys which are not solid solutions for large and small concentrations of antimony are mechanical mixtures of two crystalline phases.

The electrical conductivity and the temperature coefficient are

FIG. 22.



by Konstantinow and Smirnow [68] and the magnetic susceptibility by Leroux.[69] The initial decrease in the electrical conductivity, the temperature coefficient of the resistance and the thermoelectric power [70] caused by the addition of tin to antimony give evidence

[68] "Annual Tables of Constants and Numerical Data," Vol. 2, p. 345.

[69] Leroux: *C. R.*, 156, 1764, 1913.

[70] Hutchins: *Jour. Am., Amer. Jour. Sci.*, **48**, p. 226, 1894.

of the formation of a solid solution over this region. On the other side of the diagram where the concentration of antimony is less than 10 per cent. the curve for the electrical conductivity and for the temperature coefficient show again the presence of solid solutions. The curve for the magnetic susceptibilities indicates the compound by a change in its curvature at that concentration. The evidence for the structure of this series is not conclusive.

Lead-Thallium.

The freezing point curve for lead-thallium alloys has a very flat maximum between 30 and 40 per cent. lead. This was regarded by Lewkonja[71] as evidence of the compound $PbTh_2$. Kurnakow and Puschin[72] found that this maximum is displaced by the addition of tin to the alloys. If the maximum were due to a true compound, this displacement should not occur. Hence the existence of the compound is in doubt. Thallium forms a solid solution with lead until the concentration of thallium is about 75 per cent., and lead dissolves in thallium until the concentration of lead is about 4 or 5 per cent. Rejecting the evidence for the existence of the compound, the alloys between 5 and 25 per cent. lead are heterogeneous mixtures of a saturated solution of lead in thallium with a saturated solution of thallium in lead.

The electrical conductivity and the mean temperature coefficient as determined by Kurnakow and Schemtschuschny[73] have been plotted in Fig. 23. There is a minimum in both curves. This minimum is in the region over which lead and thallium form an isomorphous mixture. The addition of lead to thallium causes a decrease in the electrical conductivity and also in the temperature coefficient of the résistance. This decrease is followed by an increase which extends to the concentration at which the solution is saturated with lead. Between 5 and 25 per cent. lead there is a straight line portion in the curve. This is over the region where the alloys are mechanical mixtures of two crystalline phases. The pressure required to produce flow in these alloys is taken from these same observers. The curve thus obtained shows the characteristic relation between the electrical and the elastic properties.

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[71] Lewkonja: *Zeit. anorg. Chem.*, **52**, 452, 1907.

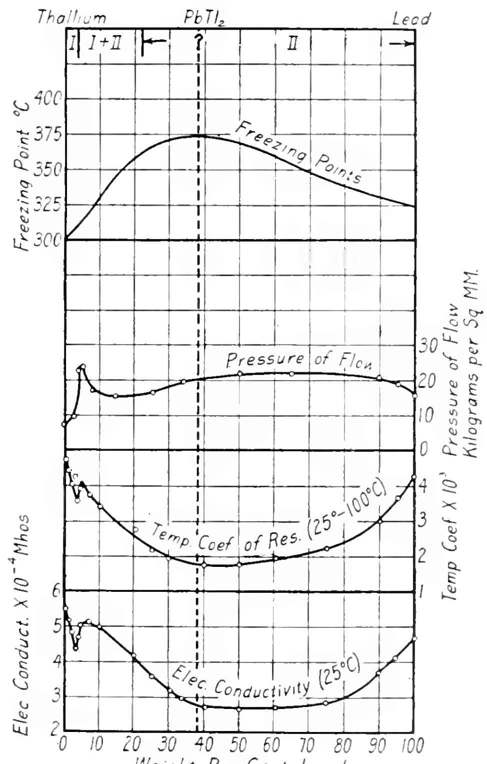
[72] Kurnakow and Puschin: *Zeit. anorg. Chem.*, **52**, 430, 1907.

[73] Kurnakow and Schemtschuschny: *Zeit. anorg. Chem.*, **64**, 156, 1909.

Lead-Antimony.

The freezing point curve (Fig. 24) by Gontermann [74] shows a eutectic in the neighborhood of 13 per cent. antimony. Gontermann finds some evidence of an intermediate crystalline constituent. Aside from this possible exception these alloys may be considered mechanical mixtures.

FIG. 23.

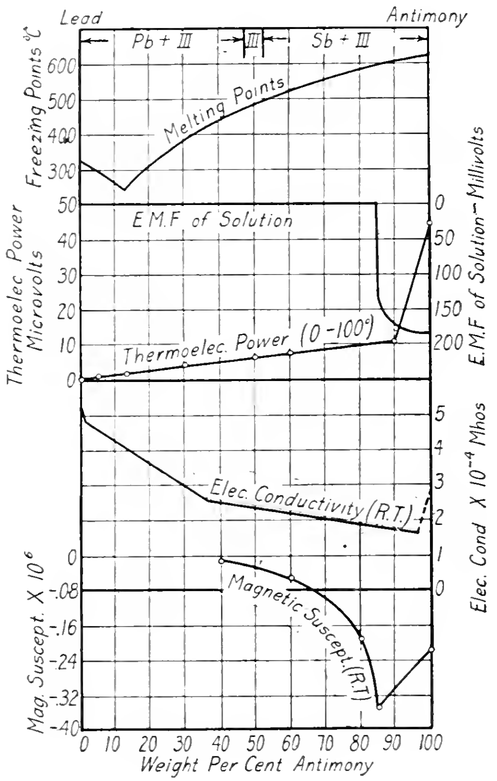


The curve for electrical conductivities is by Matthiessen; [75] for the thermoelectric powers by Rudolfi; [76] for magnetic susceptibilities by Leroux, [77] and for the electromotive force of dissolution by Pouchine. The curve for the thermoelectric powers is a straight

[74] Gontermann: *Zeit. anorg. Chem.*, **55**, 419, 1907.
[75] Matthiessen: *Pogg. Ann.*, **110**, 28, 1860.
[76] Rudolfi: *Zeit. anorg. Chem.*, **67**, 65, 1910.
[77] Leroux: *C. R.*, **156**, 1764, 1913.

line until the alloy contains 90 per cent. antimony. At that concentration the thermoelectric power rises rapidly to its value in pure antimony. At about this same concentration the curve for the magnetic susceptibilities and for the electromotive forces of solution show peculiarities. There seems to be nothing in the struc-

FIG. 24.



ture of the alloys to offer an explanation of this sudden change in the direction of the curves at this concentration.

Copper-Cobalt.

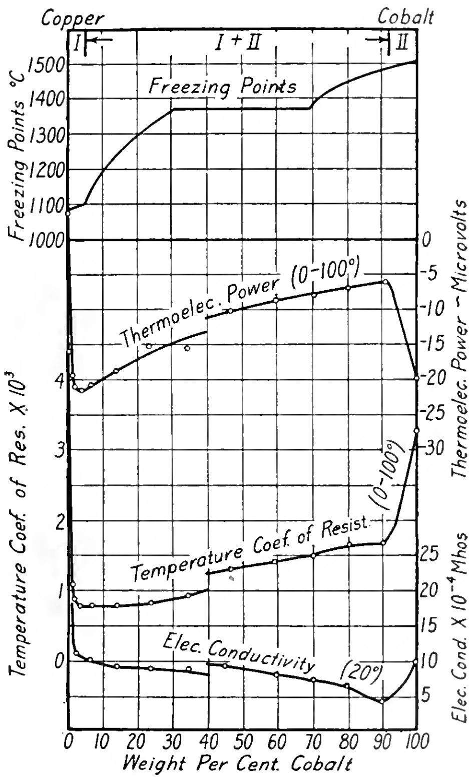
The equilibrium diagram by Sahmen [78] from which the freezing point curve (Fig. 25) is taken shows that copper and cobalt form mixed crystals with each other over a limited region. Cop-

[78] Sahmen: *Zeit. anorg. Chem.*, 57, 1908.

per is soluble in cobalt up to 8 per cent. and cobalt in copper up to 5 per cent. cobalt. The remainder of the alloys are a heterogeneous mixture of a saturated solution of cobalt in copper and a saturated solution of copper in cobalt.

The curve for electrical conductivity, temperature coefficient and thermoelectric height are from the observations of Reichardt.[79]

FIG. 25.

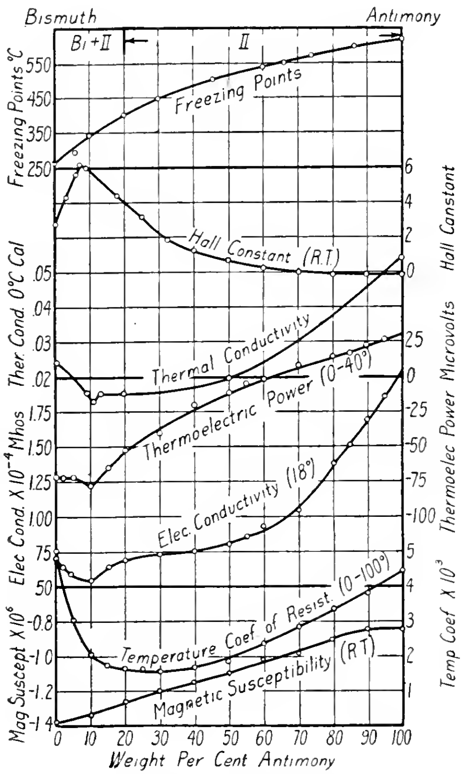


Each of these curves shows a discontinuity since alloys with less than 60 per cent. copper were so brittle that they could not be forged into wires and were investigated in the form of castings. Aside from these discontinuities the curve for electrical conductivity and the curve for temperature coefficient of resistance are typical of alloys in which the constituents are soluble in each other

[79] Reichardt: *Ann. d. Phys.*, **6**, 842, 1901.

to a limited extent. The central portion of the curves are essentially linear, as they should be for alloys formed by the mixture of two crystalline phases. The curve for thermoelectric powers is peculiar in view of the fact that the addition of cobalt to copper causes a rapid decrease in the thermoelectric height and the addition of copper to cobalt causes a somewhat less rapid increase in the thermoelectric height of cobalt.

FIG. 26.



Bismuth-Antimony.

The freezing point curve (Fig. 26) by Huttner and Tammann [80] shows that the freezing points of these alloys decrease gradually from the melting point of bismuth. Concerning the structure of the alloys there seems to be some doubt. Between 18

[80] Huttner and Tammann: *Zeit. anorg. Chem.*, 44, 131, 1905.

and 100 per cent. antimony they may be considered solid solutions of bismuth and antimony and between 0 and 18 per cent. antimony they are mixtures of bismuth and a saturated solution of antimony and bismuth.

The thermoelectromotive forces of this series have been studied by Seebeck, Rollmann, Matthiessen, Becquerel, Sundell, Battelli, Hutchins and more recently by Haken [81] from whose data the curve of Fig. 26 is taken. The electrical conductivity is known from the work of Matthiessen, Calvert and Johnason and Haken.[81] The magnetic susceptibility by Honda and Sone [82] is a linear function of the concentration until the alloy contains about 90 per cent. antimony where the proportionality fails. The curve for the thermal conductivities by Gehlhoff and Neumaier [83] is very similar to the curve for electrical conductivities by Haken. This shows that Wiedmann and Franz's law holds approximately for these alloys. The curve for the temperature coefficient is characteristic of alloys which are solid solutions. The Hall constant [84] is evidently closely related to the thermoelectric power in agreement with the suggestion of Beattie that there is a proportionality between these two quantities.

[81] Haken: *Ann. d. Phys.*, **32**, 291, 1910.

[82] Honda and Sone: *Sci. Repts. Univ. Tokio*, **2**, 5, 1913.

[83] Gehlhoff and Neumaier: *Verh. d. Deutsch. Phys. Ges.*, p. 876, 1913.

[84] Smith: *Phys. Rev.*, **32**, 178, 1911.

(*To be continued*)

Geographical Determination of Hexagonal and Tetragonal Crystal Structures from X-ray Data. A. W. HULL and W. P. DAVEY. (*Phys. Rev.*, May, 1921.)—The determination of the crystal structures from the diffraction patterns formed by X-rays that have traversed the substances considered is steadily proceeding. Plots abound in this paper, such as will lighten the work of the investigator in this field. In a second paper in the same journal the first of the two authors gives the results of his examination of thirteen common metals. Taking the first metal, chromium, it is stated that it has for its lattice-type the body-centered cube; that the side of its elementary cube is 2.895 angstroms; that the distance between nearest atoms is 2.508 angstroms, and finally that its density calculated from X-ray comes out 7.07, while its value by experiment 6.92.

G. F. S.

Colorimetric Determination of Hydrogen Ion Concentration.—In the determination of the hydrogen ion concentraction in liquids colorimetrically by means of indicators, an indicator is usually added to several cubic centimetres of the liquid. LLOYD D. FELTON, of Johns Hopkins University (*Journ. Bio. Chem.*, 1921, xlvi, 299–305), has devised a procedure by which the hydrogen ion concentration may be determined, using only a few drops of the liquid. Several individual drops of the liquid are placed on a white porcelain plate, and a drop of a different indicator solution is mixed with each drop of the liquid. The resulting color shows the hydrogen ion concentration of the liquid. In order to increase the range of each indicator solution, and thereby to decrease the number of indicator solutions required, Felton recommends use of double indicators; a solution is prepared containing two indicators which show opposite color changes; the color of one indicator is intensified in solutions of increasing hydrogen ion concentration, while the color of the other indicator is intensified in solution of decreasing hydrogen ion concentration. Such double indicators and their range for hydrogen ion concentration (pH) are: thymol blue plus bromphenol blue pH 1.2 to pH 4.6, methyl red plus bromthymol blue pH 4.6 to pH 7.6, methyl red plus bromcresol purple pH 4.6 to pH 7.0. A mixture of methyl red and thymol blue may be used for rough determinations of hydrogen ion concentration between pH 4.6 and pH 9.0. The determination may always be rendered more accurate by comparison of the colors obtained in the determination proper with colors yielded by the indicators when mixed with buffer solutions of known hydrogen ion concentration.

J. S. H.

Chemistry of Ink.—A study of this subject has been made by C. AINSWORTH MITCHELL (*Analyst*, 1921, xlvi, 129–135). Iron gall ink contains a soluble ferrous tannate. In the process of drying, this compound undergoes a gradual oxidation and changes first into colloidal, then into insoluble tannates of iron. This oxidation is accelerated by the presence of certain catalysts, but may be arrested if the solution be sufficiently acid. Addition of acids, such as sulphuric acid, oxalic acid, or, preferably, hydrochloric acid, within certain limits preserves the ink as a stable solution or colloidal suspension. When the ink is used, evaporation occurs, and an insoluble, resinous iron tannate is formed. Iron gallate inks, which are manufactured from ferrous sulphate (copperas) and gallic acid, are stable liquids, and therefore do not require the addition of acids as preservatives. If ink be placed in bottles of "alkaline" glass, the alkali gradually dissolves in the ink, changes the color of the latter, and causes a deposition of the pigment.

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SOME FACTORS AFFECTING THE LIFE OF MACHINE GUN BARRELS.[1]

By W. W. Sveshnikoff.

[ABSTRACT.]

STAR-GAGE measurements made on six machine-gun barrels at various stages of firing indicate that when the life limit is reached exhaustion is due to a combination of the abrasive action of the bullet and the abrasion by hot gases.

The author's experiments using the electric arc show that the rapid cooling (which is due to the large mass of cold metal near the highly heated inner surface of the steel) from temperatures near the melting point of the metal produces a martensitic layer. A similar layer is produced in firing of a machine gun, indicating that the temperature conditions for development of martensite by the electric arc are similar to those in the gun under actual fire.

The selective hardening of the steel sets up surface strains, and the surface of the bore is readily cracked on account of the dimensional changes of the hardened brittle surface of the steel resulting from sudden changes in temperature between separate shots. The cracks originate at irregularities in the surface of the bore, attributable to the method of manufacture of the barrels.

TESTS OF CENTRIFUGALLY CAST STEEL.[2]

By George K. Burgess.

[ABSTRACT.]

THE production of metal castings by the centrifugal process for certain non-ferrous metals and cast-iron shapes may be said to have passed beyond the experimental stage. In the case of steel

* Communicated by the Director.

[1] Technologic Paper No. 191.

[2] Technologic Paper No. 192.

very little appears to have been published regarding the properties of the metal thus cast.

Opportunity was given to the Bureau of Standards to examine in detail the physical and chemical characteristics of six centrifugal castings made by the Millspaugh process. The results are interesting in showing what may be expected from such metal as compared with the product of the more familiar manufacturing processes. The advantages to be expected from centrifugally cast steel are physical soundness and freedom from chemical segregation and thus the elimination of waste metal to be discarded, which last is always a very important factor in other processes of manufacture. For certain shapes forging and boring operations may be eliminated. The investigation shows that highly satisfactory castings which are physically sound and free from serious segregation may be produced by the centrifugal method. It is shown that the properties of these castings can be improved greatly by subsequent heat treatment such that the metal may be put in a condition to compare favorably with metal that has been forged.

A Study of the Radiation from the Vault of the Sky.—J. Vallot. (*Comptes Rendus,* May 9, 1921.) From his success in calibrating the Arago actinometer the author has been able to undertake this investigation, which was carried out at Nice. The whole flux of radiation above the surface of the earth at any time of day is the sum of three constituents, the direct radiation from the sun, the radiation from the earth itself and that from the sky. The sum of the two last contributions amounts to about one-third of the direct radiation, taking an average throughout the year, while the vault of the sky furnishes one-fourth as much as comes direct from the sun. Of the total flux the earth is the source of about 7 per cent. Of course the results would be quite different in a climate less delightful than that of the Riviera, or even there, if all days were considered and not only those without cloud.

G. F. S.

Utah's Lofty Mountains.—Utah has many lofty mountain peaks. Six of them rise more than 13,000 feet above sea level and nearly sixty rise above 12,000 feet, according to the United States Geological Survey. The highest mountain in the State is King's Peak, which has an elevation of 13,498 feet. Mount Emmons and Gilbert Peak, both in Utah, are also high mountains, reaching elevations of 13,428 and 13,422 feet, respectively.

NOTES FROM NELA RESEARCH LABORATORY.*

COLOR TEMPERATURE OF HIGH EFFICIENCY LAMPS.

By W. E. Forsythe.

THE efficiency and life of incandescent lamps depend upon the temperatures at which they are operated, the efficiency being greater for high temperatures and life shorter. Lamps are therefore operated at temperatures which will give the desired life. The integral color of the light given by the lamp also depends upon the temprature, the light being bluer for the higher temperatures.

It has been found by experiment that the light from incandescent lamps can be matched in color with that from a black body at some particular temperature, which temperature is called the color temperature. Making use of this fact, the quality of the light given by the different lamps can be given by its color temperature.

This color matching can be done quite accurately by the use of an ordinary Lummer-Brodhun contrast photometer. It is sometimes difficult to operate a black body of sufficient size at high enough temperatures, so that its luminous flux will match in color that of higher efficiency Mazda C lamps. For this reason different means are employed in obtaining the color standards for high temperatures. The standards of color used in obtaining the color temperature of the Mazda C lamps were obtained by measurements with a pyrometer of the relative brightness in limited parts of the red and blue ends of the spectrum of both the color standard and the black body. By this method a smaller black body at higher temperature can be used. The color standard and the black body are at a color match when they both have the same ratio of red to blue brightness.

Several different kinds and types of incandescent lamps operated at certain efficiencies have been color-matched with a black body and the results are given in Table I.

The true temperatures given are the actual temperatures of a portion of the filament far enough removed from the ends so that

* Communicated by the Director.

it is at the maximum temperature, while the color temperatures are for the lamp taken as a whole.

Lamp	W. P. S. C. P.	Temperatures Degrees K	Color Temperature
50-Watt Carbon	3.76	2115[1]	2156
50-Watt Gem	3.1	2180[1]	2195
50-Watt Tantalum	2.56	2160[2]	2260
40-Watt Mazda B	1.36	2410	2460
100-Watt Mazda C	1.00	2745	2740
500-Watt Mazda C	0.72	2835	2880
1000-Watt Mazda C	0.62	3010	2985
1000-Watt Stereopticon	0.52	3185	3175
900-Watt Movie	0.46	3290	3220

These temperatures are based upon the assumption of Wien's equation with c_2 taken as $14{,}350\mu$ degrees and upon the melting point of gold taken as 1336° K. On this scale the melting point of palladium has been found to be 1828° K. For convenience in the calibration of optical pyrometers, a black body held at the melting point of palladium is used as the point of reference.

Cleveland, Ohio,
June, 1921.

COLLOIDAL METALS AND BIOLUMINESCENCE.

By E. Newton Harvey.

(Physiological Laboratory of Princeton University. From experiments carried out at Nela Research Laboratories.)

LIGHT production by animals is due to the oxidation of a substance, luciferin, in the presence of an enzyme or catalyst, luciferase, water, and oxygen. Oxyluciferin is the oxidation product and this may be reduced to luciferin again by appropriate methods. Although luciferin from a small crustacean, *Cypridina,* will oxidize spontaneously in presence of oxygen without luciferase, it does not luminesce under these conditions, but only gives light if the catalyst is present.

For some years efforts have been made by the author to find an organic or inorganic catalyst of known composition which

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[1] True temperature calculated from brightness temperature, assuming an emissive power of 80 per cent.

[2] True temperature calculated from brightness temperature, assuming an emissive power of 48 per cent.

might take the place of the luciferase produced by *Cypridina*. The search has run in three directions:

1. The testing of various plant and animal extracts known to contain oxidizing enzymes;

2. The testing of well-known oxidizing agents, like H_2O_2, ozone, permanganates, bichromates, etc.; and

3. The testing of true oxidative catalysts, such as the salts of certain heavy metals and colloidal metal solutions, especially metals of the platinum group.

By courtesy of the Nela Research Laboratories, samples of many different metals were obtained and colloidal solutions prepared by the Bredig arc method. Samples not already in the form of wire or rod were prepared as rod by one of the physicists of the laboratory. Sols in distilled water, n/2000 NaOH, or weak albumin solution, were obtained with platinum, palladium, rhodium, iridium, ruthenium, vanadium, gold, silver, nickel iron, cobalt and copper. Some of these formed hydroxid sols; others presumably existed as suspensoids of metal particles. Not one of these solutions produced light when mixed with luciferin. They therefore will not act as catalysts for the reaction

$$\text{luciferin} + \text{O} = \text{oxyluciferin}$$

Although negative, these results are perhaps worthy of record as further evidence for the specificity of *Cypridina* luciferase. Thus far the author has found no substances capable of taking the place of luciferase in the oxidation of luciferin, although hundreds of extracts of non-luminous animals or plants and various organic and inorganic oxidizing agents have been tried. It should, perhaps, be pointed out that the luciferin of certain luminous animals can be oxidized with light production by extracts of non-luminous animals, and by oxidizing agents. This has been demonstrated by Dubois for *Pholas*, a luminous mollusc. It is not the case in *Cypridina* and certain evidence the author has been accumulating indicates that the luciferin of *Cypridina* cannot be made to luminesce by luciferase from some other luminous animals. The reaction is, therefore, specific to a high degree and future work, on which the author is now engaged, may indicate a species and genus relationship among the luciferases similar to that among the precipitins.

May, 1921.

TEMPERATURE VARIATIONS IN THE EMISSIVE POWER OF GOLD IN THE VISIBLE SPECTRUM.

By A. G. Worthing.

RESULTS here reported refer to polished gold which has been annealed by heating to a temperature of about 1250° K for several minutes.

Two methods, both making use of the disappearing-filament pyrometer, have been employed. The first method is the same as that used by the author in a similar study of tungsten. It consisted in comparing the brightness of the surface of an incandescent tubular filament of gold with that of its black-body interior as seen through a small hole in the filament wall. The second method is similar to the common method of measuring reflectivity. It consisted essentially in comparing the brightness of a light source with that of its image in a polished-gold surface.

The results at room temperature are in good agreement with those obtained by Hagen and Rubens. For the three wave-lengths, 0.66μ, 0.53μ and 0.47μ, respectively, 0.10, 0.36 and 0.63 have been obtained. At 1300° K the corresponding values are 0.18, 0.47 and 0.63. Thus, with increase in temperature there is a great increase in the emissive power in the red end of the spectrum, a relatively smaller increase in the green portion, and no appreciable change whatever for the blue light corresponding to 0.47μ.

These results show the behavior of gold on heating to be exactly similar to that found for tungsten in the near infra-red by Weniger and Pfund. Corresponding to 1.27μ for tungsten, the wave-length at which they found no change on heating, we have 0.47μ as the analogous wave-length for gold.

June 21, 1921.

Atomic Weight of Lanthanum.—By the analysis of lanthanum chloride, Gregory P. Baxter, Muneo Tani, and H. C. Chapin, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1080–1085), have obtained a value of 138.91 as the atomic weight of lanthanum.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE BASIC AMINO ACIDS OF GLYCININ, THE GLOBULIN OF THE SOY BEAN, SOJA HISPIDA, AS DETERMINED BY VAN SLYKE'S METHOD.[1]

By D. Breese Jones and Henry C. Waterman.

[ABSTRACT.]

THE monoamino acids of glycinin have been determined in a hydrolysis by Osborne and Clapp, who determined also the hexone bases by the direct isolation method of Kossel and Kutscher. Cystine was not isolated. No determination of the basic amino acids by the more recent method of Van Slyke seems to have appeared. Glycinin, prepared in accordance with the procedure of Osborne and Campbell, was analyzed by Van Slyke's method, the phosphotungstates of the bases being decomposed by the amyl-alcohol and ether method.

The percentages of the basic amino acids, calculated on the basis of the moisture and ash-free protein, were found to be as follows: Arginine, 8.07; cystine, 1.18; histidine, 1.44; lysine, 9.96; ammonia, 2.28. The Kossel and Kutscher figures given by Osborne and Clapp are as follows: Arginine, 5.12; cystine, not determined; histidine, 1.39; lysine, 2.71; ammonia, 2.56. The tryptophane, calculated according to Gortner's observation that 86.5 per cent. of the tryptophane N is converted into humin N on hydrolysis in the presence of carbohydrate, is 1.37 per cent. of moisture and ash-free protein. This figure is to be regarded as minimal, since no carbohydrate, except that occurring as an impurity in the preparation used, was present in the hydrolysis. The Van Slyke analyses were made in duplicate and agreed well throughout.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, Vol. 46, No. 3 (1921), pp. 459–462.

SOME SYNTHETIC RESINS FROM FURFURAL.[2]

By Gerald H. Mains and Max Phillips.

[ABSTRACT.]

With the improvement by the Bureau of Chemistry of the processes for the production of furfural cheaply and on a large scale, resins made from it become of economic importance. The optimum conditions for the production of fusible resins suitable for use in varnishes by the condensation of furfural with amines, ketones, and other compounds were determined. It was found that eight of these resins—furfur-aniline, furfur-α-naphthylamine, furfur-o-toluidine, furfur-zylidine, furfur-acetone, furfur-methyl ethyl ketone, furfur-amide, and furfur-sodium hydroxide resins—can be produced from materials cheap enough to make it of practical importance under present conditions. The varnish stains given by these resins in benzene and furfural solutions and their appearance when applied to oak were studied.

[2] Published in Chemical and Metallurgical Engineering, Vol. 24, No. 15 (1921), pp. 661–663.

On the Gamma Radiation and the Heat Developed by Radium and Mesothorium.—Mme. P. Curie. (*Comptes Rendus,* April 25, 1921.) Radium and mesothorium are isotopic radio-active elements whose separation by chemical processes is impossible. The distinguished Professor of General Physics in the University of Paris, unabashed by the difficulties of the case, seeks a method of determining the relative quantities of the two elements in a mixture contained within a sealed tube.

Each of them gives rise to a series of derivatives, and in the process gamma-rays are given off and heat is evolved. It would be difficult to distinguish one element from the other by the penetrating power of the gamma-rays escaping from a closed tube. The development of heat within the two elements, due to the energy of the alpha-rays, is fortunately not in direct proportion to the gamma-ray radiation. For the same strength of radiation mesothorium sets free less heat than radium does. It is therefore from a study of both the gamma-radiation and of the heat production that a way is devised of calculating how much radium is in the mixture and how much mesothorium.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY, WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.*

THE ARC RUPTURE OF LIQUID DIELECTRICS.[1]

By C. J. Rodman.

[ABSTRACT.]

LIQUIDS possessing a comparatively high dielectric strength, which are non-inflammable or semi-inflammable, and which may act as a media of low viscosity, have been subjected to high-frequency arcing beneath the liquid surface. A high-potential, high-frequency generator, having a maximum potential of 100,000 volts and a frequency of approximately 330,000 cycles, was used to disrupt the oil contained within a convenient vessel between two accurately adjustable ball electrodes.

Halogenated aliphatic and aromatic hydrocarbons, as well as mixtures of these with some mineral oils, were subjected to breakdown. Finely divided and highly non-conducting amorphous carbon, saturated and unsaturated hydrocarbons lower in the series, hydrochloric acid (from chlorinated compounds) and a number of gases were obtained. These gases consisted chiefly of hydrogen and unsaturates with small amounts of carbon monoxide, carbon dioxide, methane and nitrogen.

With an increase of halogenation of the oils a decrease in gas eliminated per K. W. sec. arc rupture was noted. The normal amount of gas obtained per K. W. sec. from a mineral oil was approximately 65 c.c., whereas that volume obtained from a highly chlorinated oil was as low as 20 per cent. of that amount. The gas obtained in the latter case is non-explosive when ignited with air mixtures.

The liquid dielectrics are apparently broken down by a temperature pressure effect of very short duration, rather than by the sympathetic vibration and rearrangement of the compounds by high frequency alone.

* Communicated by the Manager.

[1] Scientific Paper No. 103.

Grindstones and Pulpstones.—According to reports submitted to the United States Geological Survey, 44,832 tons of grindstones, valued at $1,239,990, were sold in 1920. The sales in 1919 amounted to 40,755 tons, valued at $993,959. This material was produced from sandstone quarries in Michigan, Ohio, and West Virginia. The sizes of the grindstones vary greatly and are reported as square grindstones, from 1/4 inch to 8 inches in diameter, and as lathe stones, from 6 to 12 inches in diameter, and as grindstones, from less than a foot in diameter and less than a pound in weight to large stones 6 to 7 feet in diameter, 8 inches to a foot or more in thickness, and from 1 to 2 tons in weight. The prices of the stones differ according to the size and quality of the stone. The smaller sized stones, which are sold by the piece, show a much higher average value per ton than the large stones. The ordinary sizes were reported to range from $23 to $40 per ton f.o.b. (unmounted) at the quarry. The average value per short ton, of all the grindstone material sold in 1920 was $27.66; the average in 1919 was $24.39.

Pulpstones are heavy stones used for grinding wood into fine fibre for making pulp and paper. These stones are generally 54 inches in diameter and 27 inches thick and weigh about 2 tons, but some machines require stones 62 inches in diameter, 54 inches thick, and that weigh about 4 tons. The production in 1920 was 8652 tons, valued at $467,014, and in 1919 it was 6110 tons, valued at $342,056. The average value per ton was $54 in 1920 and $56 in 1919. Pulpstones were obtained from quarries in Ohio and West Virginia.

Business conditions in this industry were unsettled throughout the year, and though the demand was good the sales were lessened by difficulties with transportation and with labor.

Corrosion of Boiler-tube Due to Carbonic Acid.—B. G. Worth presented to the 39th general meeting of the American Electro-Chemical Society a paper describing an unusual corrosion of a steam boiler. All attempts to control the action by electrolytic means failed. The chemist at the plant found that a notable quantity of ferrous carbonate was held in solution by excess of carbonic acid, which is a not-infrequent condition in ground waters. It is rather remarkable that the water-softening plant was not originally adapted to deal with this condition, as it is generally evident by the change of the water from clear to a reddish turbidity on standing a short time exposed to the air, and still more quickly if aerated. Corrosion of metals by natural waters has been a subject of extensive study, and among other conditions a water containing much dissolved air, with very little scale-forming material will often produce notable corrosion, especially if the feed water is introduced by a tube terminating at the boiler wall. The corrosion is generally less if the tube is prolonged to, or near, the centre of the water-mass.

H. L.

NOTES FROM THE U. S. BUREAU OF MINES.*

PRINCIPLES GOVERNING PRODUCTION OF OIL WELLS.

By Carl H. Beal and J. O. Lewis.

The factors governing the production of oil are extremely variable. Many of them can be studied and their influence on production determined, whereas the effects of others can only be estimated. Since most of the factors are interrelated and affected by each other, many conclusions can be derived only by studying wells where one factor is stronger than the others. Some of the factors that control the oil content in a sand affect also the amount that can be recovered and the rate at which it may be obtained. The main natural influences that control production are the oil content of the sand, resistance to movement of oil through the sand, the expulsive forces and their effectiveness. The chief artificial factors are the spacing of wells, operation of the wells, and the application of stimulative processes.

Oil content is determined by the thickness, porosity, extent, and sometimes the saturation of the oil sand. The resistance depends chiefly on the porosity, size of sand grains, and viscosity of the oil. The expulsive forces are the compressed gases, the direct water pressure, and gravity. All these are interrelated in effect as regards the ultimate production, and control the manner and rate of oil flow. Their influence on oil content, ultimate production, and decline are discussed in Bulletin 194, recently issued by the Bureau.

PERMEATION OF OXYGEN BREATHING APPARATUS BY GASES AND VAPORS.

By A. C. Fieldner.

Tests were made to determine the permeability of the rubber bags of oxygen breathing apparatus to gases and vapors. As the bags showed dangerous penetration in vapors of volatile gasoline, further tests were made with separate pieces of fabrics in a special

* Communicated by the Director.

apparatus for two-hour periods, which is the time that the larger breathing apparatus is designed to be worn. All the fabrics now used by the Bureau for breathing bags proved penetrable to gasoline and benzene vapors, except one of heavy sheet rubber one-sixteenth inch thick. Also, a fabric made of two rubberized sheets cemented with a glue and glycerin mixture proved impermeable, and a fabric made of cloth impregnated and coated on one side with pyroxylin varnish showed only slight penetration. Final recommendations regarding the use of heavy rubber, glue-glycerin, or pyroxylin fabrics in breathing bags will depend on results obtained in actual use of these fabrics during the coming year in oxygen-breathing apparatus used by the Bureau.

The tests were initiated because of the death of a member of the Bureau in a gasoline tank while wearing oxygen breathing apparatus. They are more fully described in Technical Paper 272 of the Bureau, by A. C. Fieldner, S. H. Katz, and S. P. Kinney.

EFFECTS OF CRYSTALLINE PARAFFIN WAX ON VISCOSITY OF LUBRICATING OIL.

By E. W. Dean and L. E. Jackson.

ONE of the refining processes to which lubricating oils are frequently subjected effects a reduction in content of paraffin wax. The actual treatment usually involves chilling and filter pressing; the most important result accomplished from a commercial point of view is lowering of the "cold test" of the oil. The Bureau of Mines recently had occasion to ascertain the effect of changes in paraffin wax content upon the viscosity of oil and has conducted a series of experiments.

The Bureau of Mines' method for the analysis of crude petroleum, which includes determination of the viscosities of lubricating oil distillates, does not provide for preliminary removal of paraffin wax, and it has seemed advisable to determine whether this omission causes any important variation from the results that would be obtained through commercial refinery processing. It was also thought that the tests might be of some value in indicating the general effect of paraffin content upon one of the most important properties of lubricating oil.

The results indicated that the changes in content of paraffin wax cause negligible variations in the viscosity of the commercial oils, and that the value of the Bureau of Mines' method for determining the viscosity of vacuum distillation fractions from crude oil apparently is not affected by the fact that paraffin wax is not separated from the products that are tested. The tests are more fully described in a recent report (No. 2249) issued by the Bureau in mimeograph form.

HIGH-GRADE TALC AND THE CALIFORNIA TALC INDUSTRY.

By Raymond B. Ladoo.

High-grade prepared talc may be divided into two classes dependent upon use—(1) massive talc, used for lava gas-burner tips and electrical insulation, pencils, tailors' chalk, etc.; and (2) ground talc used for toilet powder. Talc of the first class, suitable for lava, is not common in this country, and has been mined in only a few localities. Talc which may be cut into crayons, tailors' chalk, etc., is more widely distributed. The production of high-grade white talc suitable for the manufacture of toilet powder is a problem which requires considerable attention. Until the last few years most of the toilet-grade talc consumed in this country was imported. A small, irregular production was obtained from North Carolina, Georgia and Virginia, but this material fluctuated so greatly in quality and quantity that it was not largely used by manufacturers of high-grade toilet powders. Deposits of high-grade talc in California have been known for some years and the war caused a remarkable increase in production from 630 tons in 1916, to 4152 tons in 1917. In 1918, California stood third in the list of talc-producing States. In the essential qualities of pure white color, freedom from grit, and fine grain size it is a well established fact that the best California talcs equal or surpass the best imported talcs. In the debatable qualities of slip and freedom from lime, some of the best California talcs equal some of the best imported talcs and in other cases excel other imported talcs. Some of the very largest consumers of toilet-grade talc have expressed complete satisfaction with the high-grade California talcs and have used them regularly in preference to Italian talc.

Therefore, it can not be truthfully said the United States produces no talcs equal in quality to imported talcs. Unfortunately many domestic consumers have been so thoroughly imbued with the alleged superiority of imported talcs that domestic talcs have not been given a fair chance. In order to make the domestic product better known, the Bureau has issued a short report on the subject.

On the Displacement of Solar Rays Under the Action of Gravitation.—H. Buisson and Ch. Fabry. (*Comptes Rendus*, April 25, 1921).—The Theory of Relativity predicts a shifting of the rays of the solar spectrum towards the red, in comparison with the same rays emitted by artificial sources. This is due to the gravitational field of the sun. Each wave-length should be lengthened by a little more than two-millionths of its terrestrial value.

As long ago as 1896, Rowland and Jewell, at Johns Hopkins, found that there was a difference between the measured lengths of the same lines obtained in one case from the sun and in the other from the electric arc. In most instances the lengths of the solar waves were the greater, though the opposite occurred also. In 1909, the authors showed that these latter anomalies disappeared when comparisons were made with light emanating from an arc in a vacuum. At that time pressure was the sole cause known to be competent to produce a general shifting of the rays. Earlier in the present year Perot has shown that the *b* line of magnesium displays no noticeable shift due to pressure, and that the difference between its two wave-lengths according to solar or terrestrial origin agrees well with the predicted Einstein value.

The authors discuss 32 similar differences for as many iron lines, and conclude that they all similarly are in accord with the predicted values within the limit of experimental error. Thus, on the hypothesis that the pressure in the reversing layer of the sun is so small that it causes no shifting of the lines, it appears that the Einstein effect is competent to explain the difference between the wave-lengths of the lines derived from the sun and from earthly sources.

G. F. S.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, June 1, 1921.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, June 1, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following report was presented for final action:

No. 2769: Variable Pressure Viscometer. The Certificate of Merit to Prof. Eugene C. Bingham, of Easton, Pennsylvania, and Mr. Henry Green, of Palmerton, Pennsylvania.

The following report was presented for first reading:

No. 2773: Photo-Elastic Method of Determining Stress.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, June 8, 1921.*)

NON-RESIDENT.

MR. GEORGE EDWARD BUXTON, 322 King Street, Pottstown, Pennsylvania.
MR. GEORGE E. CABOT, Middle Road, Montecito, Santa Barbara, California.
MR. EARL H. TSCHUDY, 7 South Fourth Street, Minersville, Pennsylvania.

CHANGES OF ADDRESS.

MR. JUDSON T. BALLARD, 1010 Chelten Avenue, Oak Lane, Philadelphia, Pennsylvania.
MR. THOMAS BILYEU, 697 E. Broadway Street, Portland, Oregon.
MR. EDWARD L. CLARK, Commercial Truck Company, Hunting Park and Rising Sun Avenues, Philadelphia, Pennsylvania.
MR. HOWARD N. EAVENSON, 4311 Bayard Street, Pittsburgh, Pennsylvania.
MR. BYRON E. ELDRED, 66 Myrtle Avenue, Flushing, Long Island, New York.
DR. JACOB S. GOLDBAUM, 4234 Spruce Street, Philadelphia, Pennsylvania.
MR. D. B. HEILMAN, Bernharts, Pennsylvania.

DR. A. E. KENNELLY, in care of Morgan, Harjes & Cie, 14 Place Vendome, Paris, France.

PROF. W. LASH MILLER, 8 Hawthorne Avenue, Toronto, Canada.

MR. J. MILLIKEN, President, Industrial Car Manufacturers' Institute, 68 William Street, New York City, New York.

DR. P. G. NUTTING, 848 First Street, Ocean City, New Jersey.

MR. JOHN C. PENNIE, Pennie, Davis, Marvin & Edmonds, 165 Broadway, New York City, New York.

MR. C. E. POSTLETHWAITE, Pressed Steel Car Company, 55 Broad Street, New York City, New York.

PROF. MONROE B. SNYDER, 111 Grand View Road, Ardmore, Pennsylvania.

MR. FRANK J. SPRAGUE, Sprague Safety Control and Signal Corporation, 421 Canal Street, New York City, New York.

NECROLOGY.

Henry Spencer Blackmore was born at Yonkers, New York, on March 10, 1868, and died at Duanesburgh, New York, on February 16, 1921. He was educated in the public schools of Mt. Vernon, New York, and in 1884 entered the New York College of Pharmacy, from which he was graduated four years later. He devoted his time to chemical investigations and devised new processes for reducing aluminum and other metals, for making alkali, caustic soda and sulphuric acid. He improved methods for the manufacture of cyanides, ammonia, alcohol, ketones, lithium salts, etc., more than 150 patents having been granted him for his various inventions. He was a member of the Chemical Societies of the United States and Great Britain. Mr. Blackmore became a member of the Institute on March 26, 1897.

Mr. Wm. B. Cogswell, Solvay Process Company, Syracuse, New York.

Mr. Joseph C. Fraley, 1815 Land Title Building, Philadelphia, Pennsylvania.

Mr. Joseph B. Rohrman, 15 Aronimink Place, Drexel Hill, Pennsylvania.

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BOOK NOTICES.

A FRENCH-ENGLISH DICTIONARY FOR CHEMISTS. By Austin M. Patterson, Ph. D. xvii-384 pages, 12mo. New York, John Wiley and Sons, Inc. 1921, $3.00 net.

Living languages grow so fast that even those who speak them cannot always keep up with the supply of new words, and still more difficult is it for foreigners to do so. The success of Dr. Patterson's German dictionary has been so marked that it is certain that he knows the principles of dictionary making, and we are not surprised to find that the present work is a most satisfactory production. The war has enriched all the more important languages with a host of terms, many of them derived from those already existing in the given languages, but many others borrowed from other tongues with more or less alteration that the exigencies of spelling and pronunciation involve. English-speaking peoples have long been familiar with the "rosbif" and "biftek" of the French restaurants, and some English words unchanged in spelling but probably much changed in utterance are now among the familiar sights in newspapers and scientific journals. "Sport," "film-pack," "roll-film" are examples.

Dr. Patterson's book will be welcome to all chemists who are called on to translate from the current literature. It contains an enormous amount of information, which is set forth in a most convenient form by the manner in which the book is printed, the type used being clear and distinct. A good deal of useful information is given in the introduction concerning the equivalencies of terminations of chemical compounds in the two languages. It is pleasing to note that the author has advised against the literal translation of the French names for salts, recommending that *"carbonate de soude"* should be rendered "sodium carbonate." Chemistry is much indebted to the group of French chemists who in the later years of the eighteenth century established a system of nomenclature which has been found to be fairly capable of expansion, but it is much to be regretted that in carrying it over into English the unnecessary "of" was retained. The work before us will meet with the same success that the author's previous German-English Dictionary received.

HENRY LEFFMANN.

La Théorie de la Relativité Restriente et Généralisée, Mise à la Portée de Tout le Monde. By A. Einstein: Traduit par Mlle. J. Rouvière. Pp. xxii-120, 12mo.

This is a French version, without any changes, of the text of the tenth German edition of Einstein's excellent and well-known booklet, of which an English translation appeared in 1920. The present publication contains a valuable preface by the well-known mathematician, Professor E. Bovel, and this will perhaps attract even those French-speaking English readers who have already acquainted themselves with the English version of Einstein's

popular presentation of his own theories. However, Mlle. Rouvière's charmingly fluent language will certainly repay the time spent on re-reading this booklet.

LUDWIK SILBERSTEIN.

THE ANALYST'S LABORATORY COMPANION. By Alfred E. Johnson, B.Sc., London. F.I.C., A.R.C., Sc.I. Fifth edition, ix–176 pages, including index. 12mo. Philadelphia, P. Blakiston's Son and Company. $3 net.

This is a collection of the usual tables for use of chemists. The author has in this edition re-calculated tables according to the international atomic weights published in 1921. The beer-analysis section has been much altered and enlarged, new tables, derived from official sources, for determining the original gravity of beer have been inserted in the place of the tables long appearing in English works. Such tables have probably been of more importance in England than in the United States and the condition is still more accentuated to-day.

The preface gives in considerable detail, the improvements which have been made, and the work in its present form will be of much use to the chemist.

HENRY LEFFMANN.

THE COMMERCIAL PHOTOGRAPHER. By L. G. Rose, former photographer for the National Geological Survey and for the U. S. Naval Gun Factory. 145 pages, index and 89 illustrations, quarto. Philadelphia, Frank V. Chambers, 1920.

The Commercial applications of photography are many sided at the present day, and the high technical skill which has been developed, both in the production of the negative and print and the making of the photogravure, has given rise to a most extensive field of work, which this book covers. The text and illustrations are principally a reprint from articles in the *Bulletin of Photography*. The author's long and varied experience qualifies him to make an excellent work, and he has accomplished this task in the volume before us. The theories of photographic procedures have been left unconsidered, and very wisely, for they are not necessary to the purposes of this book and besides, are still in many cases undecided. One has only to read the recent discussions on the nature of the latent image to see how incomplete is our knowledge of the chemistry of photography.

The volume is abundantly illustrated with photogravures of exteriors, interiors, shop and residence rooms, articles of merchandise, posters and examples of the treatment of plates that have been, by accident, wrongly exposed. Many forms of apparatus used in photography are described and shown. The photogravures have all the excellence that is so striking a feature of the *Chambers Press,* and the paper and type are fully equal in quality to the pictures. To most persons the book will appeal as a work of art, but to those who are concerned with the field to which it is devoted it will be a manual rich in information and guidance.

HENRY LEFFMANN.

COCOA AND CHOCOLATE. THEIR CHEMISTRY AND MANUFACTURE. By R. Whymper, 2nd edition, revised and enlarged. 8vo., xxi, 552 pages, contents, index, 16 plates and 38 figures in text. Philadelphia, P. Blakiston's Son & Co. $10.00 net.

This book presents a thorough and highly interesting study of the chocolate plant. Linnæus, in 1720, gave the now well-known botanical name *Theobroma cacao*, the generic name being derived from Greek words, usually rendered "food of the gods," though the exact translation might be "god food." There are several other species, some of which seem to be suitable as sources of chocolate. The author has taken pains to prevent confusion in nomenclature, for there are three important plants, the names of which are so much alike as to easily lead to error. The "coconut" (which is often incorrectly spelled "cocoanut") is from the *Cocos nucifera*, a palm far different in character composition and botanical relationship from the chocolate nut. Then, there is *Erythroxylon coca*, from which cocaine is derived and which is quite different in its nature from the other two. Mr. Whymper reserves the word "cacao" for all the forms of raw material and for the fat extracted from the bean, thus emphasizing the distinction between "cacao-butter" and "coconut oil."

Every phase of the subject is well presented. A most interesting sketch of the history of chocolate is given from which we learn that it was introduced into Europe in 1528, when Cortez returned to Spain with the spoil of his conquests. Passing over the details of the spread of the use of chocolate, over the civilized world, we are impressed by the statement (p. 22) that the United States has become the greatest consumer of the product, the importations for the year ending January 30, 1918, amounting to 180.000 tons, the value of which was over $30,000,000. Mr. Whymper has recently visited the United States and examined the cacao industries. He says that preparations are on the market that would not be considered first-class in Europe, and since much of such chocolate was sent to our allies during the war, when they were suffering from lack of their customary products, the inferior quality has tended to injure the reputation of the makers. "Chocolate factories," he says, "are springing up like mushrooms, all over the United States"; a condition which he ascribes to the introduction of prohibition, and he thinks that the improvement and extension of the chocolate industry will be an atonement for our loss of the more intoxicating beverages. It is well-known to all who have studied even slightly the chemistry of cacao, that it contains a crystalline principle, "theobromin," which is closely similar in composition to caffein.

Nearly 200 pages are devoted to the chemistry of the product and to the methods of analysis, which section is followed by an excellent bibliography. Attention is paid to every phase of the industry and the products thereof. The diseases of the plant are serious and have been extensively studied. A former Philadelphian, Dr. James Birch Rorer, has been devoting several years to the investigation of such diseases, the work having been at first undertaken in Trinidad Island, under auspices of the British Government, but he has for some time been in Equador, pursuing

the same line. The work of several other investigators is mentioned in foot notes. Canker and Black Rot are the two most serious diseases. There are also insect pests. Many pages would be needed to set forth the many interesting data in this book, which is a triumph both of scientific method and printer's skill.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 103, Performance of a 300-Horsepower Hispano-Suiza Airplane Engine, by S. W. Sparrow and H. S. White, Bureau of Standards. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

A 300-horsepower Hispano-Suiza engine has been tested at the Bureau of Standards. The program of tests was planned in coöperation with the Engineering Division of the Air Service of the United States Army and was intended primarily to determine the characteristic performance of the engine at various altitudes. The engine was operated at the ground, at 25,000 feet, and at intermediate altitudes, both at full load and at loads similar to those that would be imposed upon the engine at various speeds by a propeller whose normal full-load speed was 1800 r.p.m. Friction horsepower also was determined in order that the mechanical efficiency of the engine might be calculated.

From the test data there were computed the brake horsepower; brake mean effective pressure; specific fuel consumption; mixture ratio; jacket loss; exhaust loss; and thermal, mechanical, and volumetric efficiences. A record of jacket water, temperatures, oil temperatures, manifold pressures, etc., shows the conditions under which the test was made.

A brake horsepower of 352 was obtained at 2200 r.p.m., and a maximum brake mean effective pressure of 128 pounds per square inch at about 1600 r.p.m. The mechanical efficiency varied from 88 per cent. to 83 per cent. from speeds of 1400 r.p.m. to 2200 r.p.m., while the brake thermal efficiency based on the lower calorific value of the fuel, was about 26 per cent. over this speed range. At 1800 r.p.m., and at an air density of 0.040 pounds per cubic foot the brake horsepower was about 42 per cent. and the indicated horsepower about 47 per cent. of that at the ground.

Report No. 106, Turbulence in the Air Tubes of Radiators for Aircraft Engines, by S. R. Parsons, Bureau of Standards. 13 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921.

The existence of turbulent flow in the air passages of aircraft radiators and of variations in character or degree of turbulence with different types of construction is shown by the following experimental evidence:

1. Pressure gradients along the air tubes are roughly proportional to the 1.7 power of the speed, which is characteristic of turbulent flow in long circular tubes of the same diameter.

2. The surface cooling coefficients of radiators vary widely (0.002 to 0.007) when expressed as heat dissipated per unit time, per unit cooling surface, per unit temperature between air and water, and at a given average linear speed through the tubes.

3. A fine wire, electrically heated, shows different cooling coefficients in the air tubes of different radiators.

4. Temperature gradients in the air tubes are of the form characteristic of turbulent flow and fail to show sudden breaks such as might indicate a dividing line between regions of viscous and of turbulent flow.

The use of special devices for increasing turbulence may increase the heat transfer per unit surface for a given flow of air through the radiator but such practice decreases that flow for a given speed of flight and increases head resistance. At very low flying speeds, or in cases where the radiator is mounted in the nose of the fuselage, turbulence devices may sometimes be used to advantage.

Report No. 108, Some Factors of Airplane-Engine Performance, by Victor R. Gage, Bureau of Standards. 29 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

This report is based upon an analysis of a large number of airplane-engine tests made at the Bureau of Standards and contains the results of a search for fundamental relations between many variables of engine operation.

The data used came from over 100 groups of tests made upon several engines, primarily for military information. The types of engines were the Liberty 12 and three models of the Hispano-Suiza. The tests were made in the altitude chamber, where conditions simulated altitudes up to about 30,000 feet, with engine speeds ranging from 1200 to 2200 r.p.m. The compression ratios of the different engines ranged from under 5 to 1 to over 8 to 1. The data taken on the tests were exceptionally complete, including variations of pressure and temperature, besides the brake and friction torques, rates of fuel and air consumption, the jacket and exhaust heat losses.

With the Liberty engine operating at from 500 to 2000 r.p.m., and with the Hispano-Suiza 300 horsepower operating from 1400 to 2200 r.p.m., it is found that the friction torque increases approximately as a linear function of engine speed at a given air density, and approximately as a linear function of density at a constant speed. This means that the friction horsepower increases approximately as the square of the speed. Actually the relation of torque and speed is such that the friction horsepower increases with speed raised to a power between the first and second, this power increasing with speed, approaching the square. The relation depends upon the engine design, the speed, and density of the air. Any statements as to the distribution of the friction losses are based upon incomplete evidence; the indications are however, that the pumping losses are about half of the total friction.

Report No. 110, The Altitude Effect on Air-Speed Indicators, by Mayo D. Hersey, Franklin L. Hunt and Herbert N. Eaton, Bureau of Standards. 27 pages, plate, diagrams, quarto. Washington, Government Printing Office, 1921.

The object of this paper is to present the results of a theoretical and experimental study of the effect, on the performance of air-speed indicators, of the different atmospheric conditions experienced at various altitudes. This matter has ordinarily been handled in a very simple way by following the PV^2 law and therefore correcting the observed reading of the air-speed

indicator by assuming the differential pressure developed to be directly proportional to the density and independent of any other physical property of the air.

Thermodynamic formulæ are available indicating the probable performance of Pitot tubes at high speeds where compressibility has to be considered, but all efforts which have thus far been made to arrive at a sufficiently complete formula for the Venturi tube by purely deductive reasoning have proven impracticable, on account of the difficulty of treating viscosity and turbulence. An adequate method of analysis for such problems has, however, been found in dimensional reasoning, for by this means the minimum number of experimental data needed for providing an absolutely complete inductive rather than deductive solution can be determined. In this way in the present paper the general form of the size of the instrument, its velocity through the air, and the density, viscosity, and elasticity of the medium have been derived.

The experiments reported all relate to Venturi tubes. They include water-channel experiments to determine the degree of dynamical similarity attainable between air and water and to discover whether compressibility has to be taken into account; observations in a wind stream at reduced pressure, *i. e.*, a vacuum wind tunnel, to determine the effect of density and viscosity; airplane observations as a practical check on the laboratory results; also ordinary wind-tunnel tests.

This investigation is primarily of importance in connection with low-speed or high-altitude flight, for the altitude correction under the conditions of high-speed flight near sea level is sufficiently well given for most instruments by the simple PV^2 law.

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The Case for Chemical Warfare, by Sir William J. Pope, K.B.E. Reprinted from *The Chemical Age*, May 7, 1921. 8 pages, 8vo.

The Nipigon Development, by T. C. James, Assistant Engineer, Hydro-electric Power Commission of Ontario. 11 pages, plates, 8vo. Reprinted from *The Bulletin* of the Commission, January-February, 1921.

Études Elementaires de Météorologie Pratique, par Albert Baldit. 347 pages, illustration, 8vo. Paris, Gauthier-Villars et Cie, 1921. Price 15 francs.

Dry Ammonia.—According to H. W. Foote and S. R. Brinkley, of Yale University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1178–1179), if dry ammonia be passed into a heavy-walled bottle, which is provided with an inlet tube and an outlet tube (each containing a stop cock) and is almost filled with anhydrous ammonium thiocyanate, this salt acts as an absorbent for the ammonia. The temperature must be kept at 0° C. As absorption occurs, a liquid is obtained. This liquid contains approximately 45 per cent. of ammonia when saturated with that gas at atmospheric pressure and a temperature of 0° C.; the absorption is extremely rapid. The ammonia may be stored in this manner, and may be drawn off in the anhydrous state through the outlet tube. The pressure at which delivery occurs depends on the temperature, and the latter is readily controlled by means of a water bath in which the bottle is placed. J. S. H.

CURRENT TOPICS.

Potash Salts in Texas.—Samples of salts recently sent from western Texas to the laboratories of the United States Geological Survey, at Washington, D. C., and of the Texas Bureau of Economic Geology and Technology at Austin, Texas, contain percentages of potash that suggest at least the richness of the potash deposits of Alsace and Germany. The samples were obtained from two borings about eighty miles apart, sunk by oil companies in the "Red Beds" region of Texas, where salt beds, red shales, gypsum, and other materials are associated in strata of nearly the same geologic age and general character as the potash-bearing beds of western Europe. The thickness of the potash-bearing beds in Texas represented by these samples is unknown, however, and the questions remain to be determined whether the deposit is thick enough to furnish potash in as great amount and of as high a grade as those in Europe, or whether it is of scientific interest only and mainly important as showing that potash-rich salts were actually deposited in this region, and that other borings in areas where similar beds occur may discover commercial deposits.

The problem of recognizing the presence of a thin bed of potash salt, of determining its thickness, and of identifying its precise position in the stratigraphic column is rather difficult, however, on account of the adverse conditions of observation, the methods of drilling, and sometimes the indifference of the driller. Among the samples recently examined was one from the Bryant well, in Midland County, Texas, which, as shown by a rough field test, is very rich in potash. Subsequent accurate determination in the laboratories of the Texas State University and of the Geological Survey in Washington showed that this sample which was saved by the driller from cuttings taken at depths between 2405 and 2525 feet contained about 9 per cent. of potash (K_2O). The sample consisted of red salt, including polyhalite, white salt, crushed red shale, and mud, so that the fragments of red salt ground up in the cuttings probably represent a layer that is richer in potash even than the sample as a whole.

A small piece of red salt brought out from a depth of about 1864 feet in the Burns No. 1 well of the La Mesa Oil Company, which is about eighty miles from the Bryant well, contained about 10 per cent. of potash (K_2O).

Adequate information as to even the probable thickness of the bed represented by the samples of potash salt is lacking for both these wells. The drill records of the La Mesa well indicate that the bed struck at a depth of 1864 feet may not be more than a

foot thick. On the other hand, the potash in the Bryant well in Midland County probably fills no more than a part of an interval of 20 feet covered by a single entry in the driller's log, and by a single sample of cuttings. Consequently, though a potash salt as good as that in Europe was laid down in Texas under probably similar conditions and at about the same time, in association with rock salt and other saline deposits, the important points yet to be determined by the drill are whether the potash deposits of western Texas are thick enough to be mined at a profit, whether we have in our own country ample supplies of relatively cheap potash for use in fertilizer, and whether these deposits possibly constitute a great potash reserve that will make the United States independent of foreign importations.

Dissociation of Hydrogen and Nitrogen by Electron Impacts. A. L. HUGHES. (*Phil. Mag.*, May, 1921.)—Langmuir found that hydrogen is dissociated by tungsten at a temperature above 1300° K. According to his calculations 84,000 calories are needed to dissociate a gram-molecule of the gas. From this it is calculated that the energy to dissociate one molecule is the energy given to one electron in falling through a potential of 3.6 volts. The present investigator set out to see whether electrons falling through this potential interval really do dissociate any molecules of hydrogen by impact. He finds that dissociation is not observable until the interval of potential reaches 13.3 volts.

The hydrogen for the experiment was contained in a glass tube jacketed with liquid air. Along its axis was a platinum strip coated with BaO and SrO. When heated by an electric current this became a source of electrons. Nickel gauze, fitting as a cylinder into the tube, served as an anode toward which the electrons were driven from the platinum cathode by an applied difference of potential. The pressure of the hydrogen ranged from .1 mm. downward. The stream of electrons was started and then readings of pressures of the gas under experiment were taken at intervals of 4 minutes. There was always a diminution of the pressure with the passage of time. For instance, to quote a single series of readings, the pressure fell from 200×10^{-5} mm. to 8.8 of the same unit in 40 minutes. The absolute change of pressure becomes smaller as the pressure of the hydrogen is reduced, but the ratio of initial to final pressure rises as the initial pressure is made smaller. As the voltage between the electrodes was raised the rate of pressure change likewise rose and reached a maximum for about 140 volts, to decline somewhat for values in excess of 150 volts.

Why does the pressure fall while the electron stream continues? The author adopts the explanation advanced by Langmuir to account for similar results which were obtained when dissociation was produced by high temperature, *viz.*, that atoms of hydrogen, resulting from dissociation, condense progressively on

the cold surface of the tube. This has at least the merit of furnishing a ready elucidation of a phenomenon which manifests itself when the experimental tube, in which the gas pressure has grown smaller owing to the electron stream, is heated, and then cooled. Upon heating the pressure rises of course, but subsequent cooling to the temperature of the bath does not reduce the pressure to its former amount when the hydrogen was at the same temperature. To cite one such experiment, pressure before the electrons passed in hundred-thousandths of a millimetre, 548; after their passage, 100; after re-heating and re-cooling, 263. It is held that, when the temperature goes up, some of the atoms of gas condensed on the cold walls get free and re-combine into molecules. When the temperature again falls these remain molecules and are not condensed as they were at the same temperature, while in atomic form.

G. F. S.

Preparation of Zirconia from the Ore.—E. C. ROSSITER and P. H. SAUNDERS describe their process for the preparation of zirconia (zirconium dioxide) from the ore in *Journ. Soc. Chem. Ind.* Trans., 1921, xl, 70–72. The ore is finely ground in a porcelain ball mill; 50 grams of the ground ore are mixed with an equal weight of sodium hydroxide; and the mixture is heated in an iron crucible with continuous stirring until a granular powder is obtained. The temperature is then raised to a just visible redness, and finally becomes approximately 600° C.; two hours are required for fusion of the mixture. While still hot, the contents of the crucible are treated with 1500 c.c. of water. The insoluble portion is collected on a filter, and is washed with water until free from alkali, then is treated with hydrochloric acid. The resulting solution contains insoluble matter, and is evaporated to dryness without filtration. The residue is extracted with hot water; the solution is filtered, and the filtrate contains zirconium oxychloride and the chlorides of certain metals such as iron, aluminum, and manganese. The solution is diluted to a volume of 1500 c.c.; and sulphurous acid is added in amount slightly in excess of that required to reduce the iron present in the solution completely to the ferrous state. Then the solution is heated to boiling, and normal sulphuric acid is added in amount theoretically required to replace the chlorine content of the oxychloride. All of the zirconium present in the solution precipitates as a basic sulphate. For quantitative results, 7 c.c. of a saturated solution of sulphurous acid and 2 c.c. of a normal solution of sulphuric acid should be used for each 0.2 gram of zirconium dioxide; and the solution containing the zirconium should be so dilute that it has a volume of at least 150 c.c. for each 2 c.c. of normal sulphuric acid to be added. If the precipitate be washed five times by decantation in a glass cylinder of 6 litres capacity, the soluble impurities are

reduced to 0.3 per cent. of the amount originally present, and less than 1 part of iron in 100,000 is present. In order to obtain zirconia, the basic sulphate may be dried and ignited; or it may be suspended in water and treated with an alkali with the production of zirconium hydroxide, the latter compound is then washed, dried, and ignited. In either case, the final product contains from 98 to 99 per cent. of zirconium dioxide; silica and a smaller amount of alumina are also present. J. S. H.

On the Supposed Weight and Fate of Radiations. SIR OLIVER LODGE (*Phil. Mag.*, April, 1921).—This, the first article in a monthly number of the great British magazine, should, in justice to the author be read in the light of the opening sentences. "In regions where our ignorance is great, occasional guesses are permissible. Some guesses occur in this paper: let an apology for them be understood.

"If light is subject to gravity, if in any real sense light has weight, it is natural to trace the consequences of such a fact. One of these consequences would be that a sufficiently massive and concentrated body would be able to retain light and prevent its escaping."

The author then works out the mathematics of the problem and draws the conclusion, "We find that a system able to control and retain its light must have a density and size comparable to

$$\rho R^2 = 1.6 \times 10^{27}$$

where ρ is the density and R the radius, both in c. g. s. units." "It is hardly feasible for any single mass to satisfy this condition; either the density or the size is too enormous." "If a mass like that of the sun could be concentrated into a globe about 3 kilometres in radius, such a globe would have the properties above referred to; but concentration to that extent is beyond the range of rational attention. The earth would have to be still more squeezed into a globe 1 centimetre in diameter." The suggestion is made that a stellar system might meet the conditions. "The question has often been asked, What becomes of all the radiation poured into space by innumerable suns through incalculable ages? Is it possible that some of it is trapped, without absorption, by reservoirs of matter lurking in the depths of space, and held until they burst into new stars? And a further more important question begins to obtrude itself: What happens to light when, in free though modified ether, it is stopped relatively to a gravitational mass? Does it retain its energy, mainly on rotational form, tie itself into electrons, and add to the mass of the body?" After an examination of this problem the author proceeds, "So if 10 cubic millimetres of earth-sunshine could be checked and condensed till its density was 10^{12} it might be converted into an electron of mass 10^{-27} gramme." G. F. S.

Phenosafranin in Photography.—Great interest has been awakened by the discovery of the strong densitizing powers of the dyestuff known commercially as phenosafranin in Europe and supplied by an American manufacturer under the title Safranin A. extra. Dr. Lüppo-Cramer, Technical Director of Kranseder & Co., Munich, whose fame in photographic research is international, called attention to the peculiar property that dilute solutions of this color have in diminishing the sensibility of exposed plates without appreciably affecting the latent image. As might be expected, many other substances have similar properties, but none so far examined equals phenosafranin. Solutions of not over one part of the color to 2000 of water are efficient, and such solution keeps. Lüppo-Cramer has further found that the dye markedly accelerates the action of hydroquinone, and that it also acts as preservative of developers. A solution of the material has recently been put on the market by an English firm under the title "Desensitol." This is a very concentrated solution, and is directed to be diluted to about fifty times for use. A. and L. Lumiere and Seyewitz have recently presented a communication to the French Photographic Society, detailing the results of many experiments to determine what other substances are densitizers. The paper has appeared in very full abstract in a recent issue of *La Revue Française de Photographie*. Lüppo-Cramer has published a small book giving an account of his researches in the field, and discussing some of the theories of the action.

H. L.

Note on the Possibility of Separating Mercury into Its Isotopic Forms by Centrifuging. J. H. J. POOLE. (*Phil. Mag.*, May, 1921.)—According to Aston's results mercury is a mixture of six isotopes having atomic weights of 197, 198, 199, 200, 202 and 204. To simplify the problem of finding on theoretical grounds whether it be possible to separate the liquid into its isotopes by centrifuging several assumptions are made. Only two isotopes are considered at present, and these have a difference in atomic weight of 4 units. They are in approximately equal amounts and are supposed to differ only in mass; all other constants being the same for both. Mercury is regarded as incompressible.

The conditions of equilibrium for such a mixture in a rotating tube placed in a centrifugal field of force are examined, and it is found that the difference of density between the two ends of the rotating tube would be only one part in 30,000 for 9000 revolutions per minute. So minute a difference could hardly be detected. It is suggested that a centrifuge could be made to run at 60,000 revolutions per minute, and that with this apparatus the difference of density would reach 1½ parts per thousand, which could be detected. After attaining this conclusion the author puts a curb on anticipation by saying: "The results obtained would apparently

hardly justify the expense entailed in constructing the special centrifuge." The analysis of elements into isotypes is based on the study of positive ray phenomena, which are not well known to chemists. If it be possible to verify the analysis by appeal to the familiar mechanical method of centrifuging, it is to be hoped that some means may be discovered for constructing the needed apparatus.

The author holds that, if liquid neon could be substituted for mercury, a difference in density ought to be obtained, since the two isotopes differ by 10 per cent. The difficulty of running at the temperature of the liquid would not be small.

G. F. S.

The Spectrum of Helium in the Extreme Ultra-Violet. H. FRICKE and THEODORE LYMAN. (*Phil. Mag.*, May, 1921.)—Hitherto investigations of the spectrum of helium in the Schumann region have been made of necessity by the use of a strong disruptive discharge, which introduced impurities into the gas through its action on the walls of the tube and on the electrodes. This state of affairs led to uncertainty in the origin to which the observed lines were to be attributed. Though other lines were believed by one investigator or another to be due to helium, yet in the range of wave-length from 1700 to 600 angstrom units only two lines could with assurance be assigned to helium. Within the last two years it has been found that there is a resonance potential for helium corresponding to a wave-length of about 600 units.

The gas was at a pressure of .8 millimetre of mercury. The current employed was direct and varied from 20 to 40 milliamperes. The vacuum spectroscope was smaller than its predecessor, the grating having a radius of only 20 cm. The change in dimensions materially reduced the absorption of light by gas. The helium as originally prepared was pure, but by the time it was transferred to the apparatus it sometimes had gained traces of hydrogen and of oxides of carbon. Under the new conditions of experiment the strongest line of all was that occurring at 585 units. Its authenticity was confirmed by experiments with the previously employed, larger spectroscope, with which the record of the line was faint but unmistakable. It is interesting to note that this line, whose existence is known by experiment, fits into the speculative scheme of Bohr and Sommerfeld.

G. F. S.

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THE MAGNETIC ELECTRON.*

BY

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THE evidence brought forward by the speakers who have preceded me has shown that many magnetic phenomena find a satisfactory explanation on the hypothesis that matter contains a large number of minute elementary magnets. The theories of para- and ferro-magnetism as developed by Langevin, Weiss and others, though based upon the hypothesis of such ultimate magnetic particles, make no assumptions concerning their nature. The explanation of diamagnetism, on the other hand, is based upon the view that this effect owes its origin to the circulation of electricity in resistanceless paths. The success of these theories in explaining the principal characteristics of magnetism gives us confidence in the real existence of these magnetic particles. Let us see, therefore, if it is possible to identify these elementary magnets with any of the fundamental divisions of matter.

The original investigations of ferromagnetism which led to the hypothesis of an elementary magnetic particle credited molecules with the properties of small permanent magnets. This view finds some support in the profound effect of heating, mechanical jarring, etc., on the ease of magnetization of iron. The dependence of magnetic permeability upon the chemical condition of a substance suggests the same view. But perhaps the strongest

* Based on a paper read before Section B of the American Association for the Advancement of Science, December 27, 1920.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

argument that has been brought forward in support of the idea of molecular magnets has been the discovery of the Heusler alloys, in which by melting together elements which are only slightly magnetic an alloy with ferromagnetic properties is produced. It is, however, difficult to imagine what mechanism could reasonably give to a group of atoms, such as the chemical molecule, the properties of a single magnetic particle. Moreover, if on magnetization such a group of atoms should actually turn around within a crystal, as the elementary magnets are supposed to do, the resulting change in the positions of the atoms composing the molecule should produce a change in the crystal form; since, as we know, the form of the crystal is dependent upon the arrangement of its component atoms. It is, however, a matter of common observation that a magnetic field effects no such change in the form of a magnetic crystal.

Perhaps the most natural, and certainly the most generally accepted view of the nature of the elementary magnet, is that the revolution of electrons in orbits within the atom give to the atom as a whole the properties of a tiny permanent magnet. Support of this view is found in the quantitative explanation which it affords of the Zeeman effect. It seems but a step from the explanation of this effect to Langevin's explanation of diamagnetism as another result of the induced electronic currents within the atom. On Langevin's view the electronic orbits act as resistanceless circuits in which an external magnetic field induces changes of current. By Lenz's law these induced currents will always be in the direction to give the electronic orbit a magnetic polarity opposite to the applied field, thus accounting for the atom's diamagnetic properties. This theory offers a satisfactory qualitative explanation of diamagnetism, and accounts for the fact that diamagnetism is independent of temperature. But quantitatively it is inadequate. For, in order to explain the magnitude of the observed diamagnetic susceptibility on this view, one must suppose either that the atom possesses a number of electrons equal to several times its atomic number, or the distance between the electrons in the atom must be several times as great as is estimated by more direct methods. Moreover, the experiments of Barnett [1] and J. Q. Stewart [2] show that the ratio of charge to mass of the

[1] S. J. Barnett, *Phys. Rev.*, **6**, 240 (1915).

[2] J. Q. Stewart, *Phys. Rev.*, **11**, 100 (1918).

elementary magnet, though of the same order of magnitude, is appreciably greater than one would expect if the magnetic moment is due solely to electrons revolving in orbits. But perhaps a more serious difficulty with the usual electron theory of diamagnetism is that the induced change in magnetic moment of the electronic orbit involves also a change in its angular momentum. It is obvious, according to the classical electrical theory, that any electron revolving in an orbit will soon radiate its energy. Any angular momentum induced by an applied magnetic field will, on this theory, therefore, rapidly disappear so that diamagnetism should be merely a transient effect. Let us then assume with Bohr that if each electron has some definite angular momentum such as $h/2\pi$, no radiation occurs. On this view the electrons in the normal atom will all possess the requisite angular momentum, and when an external magnetic field is applied the induced change in angular momentum will put the electrons in an unstable condition. On this view also, therefore, the additional rotational energy induced by an applied magnetic field will not be permanent, but will soon be dissipated. In fact, the theory of atomic structure has yet to be proposed according to which diamagnetism, accounted for by the induced magnetic moment of electrons revolving in orbits, can be more than a transient phenomenon.

Besides the molecule and the atom we have the other two fundamental divisions of matter, the atomic nucleus and the electron. The sign of the Richardson-Barnett effect indicates that it is negative electricity which is chiefly responsible for magnetic effects, which makes the view that the positive nucleus is the elementary magnet difficult to defend. On the other hand, many of the magnetic properties of matter receive a satisfactory explanation on Parson's hypothesis,[3] that the electron is a continuous ring of negative electricity spinning rapidly about an axis perpendicular to its plane, and therefore possessing a magnetic moment as well as an electric charge. Thus, for example, the fact that such a ring can rotate without radiating enables this hypothesis to account for diamagnetism as a permanent instead of a transient effect. While retaining Parson's view of a magnetic electron of comparatively large size, we may suppose with Nicholson that instead of being a ring of electricity, the electron has a more nearly isotropic form with a strong concentration of electric charge near the centre

[3] A. L. Parson, Smithsonian Misc. Collections, 1915.

and a diminution of electric density as the radius increases. It is natural to suppose that the mass of such an electron is concentrated principally near its centre and that the ratio of the charge to the mass of its external portions will be greater than that for the electron as whole. While the explanation of the inertia of such a charge of electricity is perhaps not obvious, it is at least consistent with our usual conceptions and it has the advantage of offering an explanation for the large value of e/m observed in Barnett and Stewart's experiments. It also makes possible an explanation of the relatively large induced currents required to account for diamagnetism without introducing the assumption of a prohibitively large radius for the electric charge.

A series of experiments has recently been performed, designed to determine which of these fundamental divisions of matter is identical with the elementary magnet in ferromagnetic substances. The first of these, due to K. T. Compton and E. A. Trousdale,[4] had for its object the detection of any displacement of the atoms of a substance on magnetization. If the elementary magnet consists of a group of atoms such as the chemical molecule, the rotation of this elementary magnet into alignment with an applied external field will cause a displacement of the individual atoms. It is known, however, that the position of the spots on a Laue photograph depends upon the arrangement of the atoms within the crystal employed. If then, such a photograph is taken with a magnetic crystal, the character of the diffraction pattern should change when the direction of magnetization of the crystal is altered. In these experiments, however, no effect of this character was found. The obvious conclusion is that the ultimate magnetic particle does not consist of any group of atoms such as the chemical molecule.

The second of these experiments, performed by Mr. Rognley and myself,[5] was based upon the fact that the intensity of reflection of X-rays from the surface of a crystal depends not only upon the arrangement of the atoms within the crystal, but also upon the distribution of the electrons within the atoms. Let us suppose that the atom acts as a tiny magnet due to the orbital motion of its component electrons. Magnetization of the crystal will orient these atomic magnets and in so doing will change the planes of

[4] K. T. Compton and E. A. Trousdale, *Phys. Rev.*, **5**, 315 (1915).

[5] A. H. Compton and O. Rognley, *Phys. Rev.*, **16**, 464 (1920).

revolution of the electrons. This change in the electronic distribution should, therefore, affect the intensity of reflection of a beam of X-rays from the crystal's surface. An attempt was made to detect such a change in the intensity of X-ray reflection from a crystal of magnetite when strongly magnetized. Apparatus sufficiently sensitive to detect a change in intensity of less than one per cent. was employed, but magnetization of the crystal failed to produce any measurable effect. The following table shows in the first column the order of the X-ray spectrum line which was being studied; in the second column

TABLE I.

Order	E_1/E_u	E_2/E_u	E_3/E_u
1	1.05	1.000	1.004
2	1.27	0.96	1.03
3	1.48	0.86	1.09
4	1.70	0.51	1.09

the calculated ratio of intensity from the magnetized to that from the unmagnetized crystal, supposing the atom to have the Rutherford form; and the third and fourth columns represent the similar ratios as estimated from a cubic form of atom. In the third column it is supposed that the magnetic axis is perpendicular to a cube face, and in the fourth column that the magnetic axis is along the cube diagonal. According to experiment the value of these ratios was always unity, at least within one per cent. It is clear that none of the types of atoms considered could be oriented by a magnetic field without producing a noticeable effect. In fact, it is difficult to imagine any form of magnetic atom which would be so nearly isotropic that it would have given no effect in our experiment. It is, therefore, difficult to avoid the conclusion that the elementary magnet is not the atom as a whole.

Since neither the molecule nor the atom gives a satisfactory explanation of these experiments, the view suggests itself that it is something within the atom, presumably the electron, which is the ultimate magnetic particle. Let us see then if we can find any positive evidence for the existence of an electron with a magnetic moment.

On the basis of the classical dynamics we should expect the electron, whatever its form, to possess thermal energy of rotational motion, equal on the average to that of a molecule or atom

at the same temperature. On Planck's more recent quantum hypothesis, however, which is perhaps the more reasonable view, at the absolute zero of temperature each particle of matter—including the electron—should retain an average amount of energy ½hv for each degree of freedom for motion. For a rotating system this corresponds to an angular momentum of $h/2\pi$. Thus whatever view we adopt, the thermal motions of the electron will give to it an appreciable magnetic moment. For a particle of the small moment of inertia of the electron, the frequency of rotation corresponding to an angular momentum $h/2\pi$ will be exceedingly high, and the corresponding energy ½hv will be large compared with the additional energy which it may acquire due to an increase in temperature. Thus the angular momentum, and hence also the magnetic moment of the electron, will be nearly the same at different temperatures—a property characteristic of the elementary magnets. It is interesting to notice, also, that the magnitude of the magnetic moment of an electron spinning with an angular momentum $h/2\pi$ is of the proper order to account for ferromagnetic properties, being about one-third the magnetic moment of the iron atom.

If an electron with such an angular momentum is to have a peripheral velocity which does not approach that of light, it is necessary that the radius of gyration of the electron shall be greater than 10^{-11} cm. While such an electron is much larger than the spherical electron of Lorentz, recent experiments on the scattering of X-rays and gamma rays indicate the electron's diameter may be even greater than the minimum value thus required to explain magnetic properties. Experiment shows that the scattering of very high frequency radiation is considerably less than theory demands if the electron is supposed to have negligible dimensions. In the case of hard gamma rays, indeed, I have found the scattering at certain angles to fall below 1/1000, the intensity predicted on the usual theory.[6] The only adequate explanation of these experiments seems to be that interference occurs between the rays scattered from the different parts of the same electron. Such an explanation clearly implies that the diameter of the electron is comparable with the wave-length of the radiation employed, which means that the effective radius of the electron is of the order of 10^{-10} cm. Considerations of the size of the electron, therefore,

[6] A. H. Compton, *Phil. Mag.* (in printer's hands).

support rather than oppose the view that the electron may have an appreciable magnetic moment.

Further evidence that the electron possesses properties other than those of an electric charge of negligible dimensions is afforded by a study of the white X-radiation emitted at the target of an X-ray tube. It was noticed by Kaye that the X-rays emitted in the direction of the cathode ray beam are harder and more intense than those traveling in the opposite direction. The difference in both hardness and intensity of the radiation at different angles is in good accord with the view proposed by D. L. Webster that the particles emitting the radiation are moving in the direction of the cathode-ray beam, giving rise to a Doppler effect. Indeed, it is very difficult to give any other explanation of the difference in wave-length of the radiation in different directions. But, on this view, in order to account for the difference in hardness observed in the case of gamma rays, the radiating particles must have a velocity of about one-half the speed of light. Since the highest known speeds at which atoms travel is only about one-tenth the velocity of light, as observed in the case of alpha particles, the swiftly moving radiators giving rise to this high-frequency X-radiation must therefore be free electrons. If this view is correct, it follows, as Webster has pointed out, that the electron must be a system capable of emitting radiation, and is therefore, not a mere charge of electricity of negligible dimensions. On the present view we may well suppose that the electron is spinning like a gyroscope and on traversing matter is set into mutational oscillations, resulting in the observed radiation.

Strong evidence that the electron possesses a magnetic moment is afforded by H. S. Allen's recent explanation of the rotation of the plane of polarization by optically active substances.[7] You will remember in Drude's classical work it is found that optical rotation may be explained if the electrons, when made to oscillate by a passing electric wave, do not move exactly in the plane of the electric vector. He supposes rather that there is a component of motion at right angles to the electric vector and finds that such a motion will account for the observed rotation. Allen shows that the motion perpendicular to the electric vector which Drude assumes is a natural consequence of the view that the electron is magnetic and has an appreciable diameter. It would take us too

[7] H. S. Allen, *Phil. Mag.*, **40**, 426 (1920).

far afield to discuss the details of this work, but the significance of the result is obvious, since it has heretofore been difficult to give a reasonable account of the type of motion postulated by Drude.

Finally, I wish to discuss a phenomenon, first noticed by C. T. R. Wilson and brought to my attention by Mr. Shimizu, which, if its obvious explanation is correct, gives direct evidence that free electrons possess magnetic polarity. Suppose that a magnetic electron is placed in a homogeneous paramagnetic medium. Every part of the medium will be slightly magnetized in the direction of the lines of force, and the magnetic field at the electron due to the magnetic moment of each portion of the medium will have a positive component in the direction of the electron's magnetic axis. Thus the magnetization induced in the surrounding medium will give rise to a magnetic force at the electron in the direction of its own magnetic axis. The case is exactly analogous to placing a bar magnet in a field of iron filings. The iron filings will be magnetized by induction in the direction of the lines of force and if the bar magnet is removed, there still exists a magnetic field where the magnet was because of the magnetization of the surrounding iron filings. If now the electron is in motion, this induced magnetic field will produce the same effect as would an externally applied field of the same intensity. That is, the force due to the magnetic field from the surrounding medium acting on the moving electric charge will make it follow a curved instead of a straight path.

If, because of its gyroscopic action, the axis of the electron does not change its direction, the induced magnetic field will always be in the same direction, and the electron will describe a helical orbit. In any actual medium, composed of discreet particles and therefore not homogeneous on an electronic scale, this spiral motion will be superposed upon an irregular motion due to collisions, and the axis of the electron will not remain fixed in direction. Thus any spiral motion that may appear should be rather broken. A rough calculation, assuming an electron to be projected into air with a speed corresponding to a drop through 10,000 volts, which is about that of the secondary cathode rays produced by ordinary X-rays, and having a magnetic moment corresponding to the angular momentum $h/2\pi$, indicates that the induced magnetic field at the electron should be of the order of 3000 gauss, if the permeability of the medium is that of ordinary air. This field

is strong enough to produce a very decided curvature in the electron's path, so in spite of the irregularities in the electron's motion we might hope to observe experimentally the predicted helical tracks.

Below are a few of C. T. R. Wilson's photographs of the tracks of secondary cathode rays and beta particles. In the first figure are seen the tracks of the cathode rays ejected by a comparatively intense beam of X-rays. Let me call your attention particularly to the two tracks marked by arrows. You see here paths in the form of almost perfect helices. Most of the tracks are too

FIG. 1.

irregular and too confused with each other to trace so perfect a spiral form; but you will notice that in almost every case, the track terminates in a close spiral. The tracks can be examined more satisfactorily if we use a photograph showing a smaller number. In the next figure I have called attention particularly to three tracks. It is unfortunate that one cannot show these paths on the screen in three dimensions. Mr. Wilson showed me some remarkable stereoscopic photographs, as yet unpublished, which he obtained of X-rays passing through air. In one of these, showing altogether about 66 complete tracks, all but about 14 seemed to be of a spiral form. Of these fourteen 12 were too irregular to detect with certainty any spiral tendency that might exist, and the remaining two were for the most part straight. But to me

there seemed no doubt, nor did there to others who examined them carefully, but that there was a real tendency to spiral motion in the tracks of these secondary cathode particles.

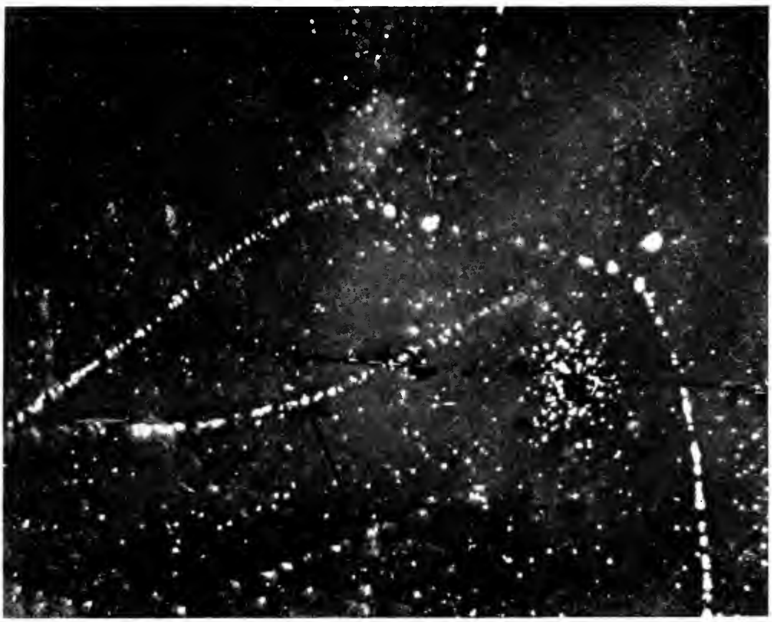
The beta rays from radium show the same consistent curvature. Notice particularly the path shown in Fig. 3 with its almost uniform curvature. If one would calculate the probability of such a curvature on the basis of chance collisions, each as likely to deflect the particle in one direction as in another, this type of path would be declared impossible.

FIG. 2.

Examining again the tracks of the secondary cathode rays, let us see how their form compares with that to be expected for gyroscopic magnetic electrons. In the first place we find that the tracks exhibit a helical curvature of the kind we should anticipate. In the second place the axis of the helix is different for each beta particle, which we should anticipate since each beta particle induces its own magnetic field and the direction of the field is coincident with its own axis. And, finally, we notice changes in the direction of curvature such as might well result from sudden precessions of the electron's gyroscopic axis. If the obvious explanation of these spiral tracks is the correct one, we have here positive evidence for our hypothesis that the electron acts as a tiny magnet as well as an electric charge.

Let us then review the different lines of evidence that have given us information concerning the nature of the elementary magnet. In the first place, the Richardson-Barnett effect shows that magnetism is due chiefly to the circulation of negative electricity whose ratio of charge to mass is not greatly different from that of the electron. In the second place, experiments on the diffraction

FIG. 3.



of X-rays by magnetic crystals indicate that the elementary magnet is not any group of atoms, such as the chemical molecule, nor even the atom itself; but lead rather to the view that it is the electron rotating about its own axis which is responsible for the ferromagnetism. And finally, positive evidence in favor of the hypothesis of some form of magnetic electron is supplied by a consideration of the curvature of the tracks of beta rays through air. May I then conclude that the electron itself, spinning like a tiny gyroscope, is probably the ultimate magnetic particle.

Substitution of Turbidity for Nephelometry. W. DENIS, of Tulane University (*Jour. Biol. Chem.*, 1921, xlvii, 27–31), states that determinations of turbidity, made by means of colorimeter, may advantageously be substituted for nephelometric determinations in a number of analytical procedures. Turbidimetric readings give quantitative results with large variations in concentration between the standard and the unknown. Therefore turbidimetric determinations may be made without the preparation of the large number of standards which are required in nephelometric work. J. S. H.

Oil of Oats. ERNEST PAUL (*Analyst*, 1921, xlvi, 238–239) has made a study of the oil obtained from oats by extraction with hot petroleum ether. The oats were dried at a temperature of 36°, and still contained 4 per cent. of moisture. They were ground, then extracted with the solvent by percolation under pressure until practically fat-free. The yield of oil was 4.32 per cent. of the dry sample. The oil contained approximately 1 per cent. of lecithin. The chemical constants of the oil resembled those of maize or corn oil. Its drying properties were determined by means of films on ground glass plates. At ordinary temperatures, gumming only commenced in two months, while a hard varnish was produced in two to three days at a temperature of 99° C. Approximately one-third of the oil was free fatty acids. J. S. H.

International Normal Weight for the Saccharimeter.—The International Commission for Uniform Methods of Sugar Analysis in 1900 adopted 26 grams as the normal weight to be used in the direct determination of the per cent. of sucrose or cane sugar by means of the polarimeter. The French generally use a normal weight of 16.29 grams. Recently the suggestion has been made to adopt a sugar scale with a normal weight of 20 grams. According to the *Analyst*, 1921, xlvi, 268, British chemists are largely in favor of retaining the present international standard normal weight, which is in almost universal use except in France and Mauritus.

J. S. H.

On a Lecture Demonstration of the Absolute Determination of Resistance. F. E. SMITH. (*Proc. Phys. Soc. of London*, vol. 33, part 3.)—The usual feeling is that any such determination as this is of a highly recondite character, yet Mr. Smith demonstrated the experiment to an audience of the London Physical Society, and allows only two or three minutes for its performance. He boldly suggests that a similar demonstration be incorporated in courses of lectures on electricity. His apparatus was based on the original British Association coil. Two coils, each of several hundred turns, were placed side by side so as to allow a magnetic needle to be suspended at the centre. They are rotated in the earth's field. Thus a current was induced in them, which deflected the needle. The exhibition of this experiment is proposed as a means of arousing interest in absolute measurements. G. F. S.

THERMAL, ELECTRICAL AND MAGNETIC PROPERTIES OF ALLOYS.*

BY

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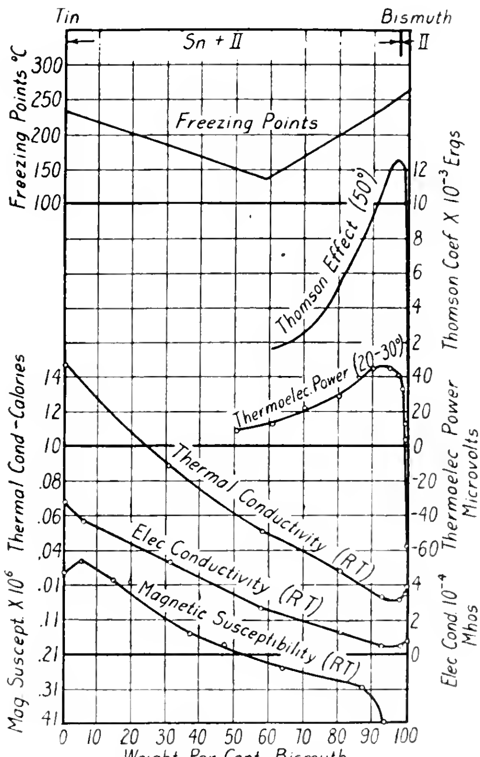
Bismuth-Tin.

The freezing point curve (Fig. 27) from data of Stoffel [85] and Lepkowski [86] consists of two branches meeting at a eutectic. Except for small and possibly large concentrations of tin where the

FIG. 27.



metals may be soluble in each other to a limited extent, these alloys are mechanical mixtures of bismuth and tin.

* Concluded from page 105, vol. 192, July, 1921.

[85] Stoffel: *Zeit. anorg. Chem.*, 53, 148, 1907.

[86] Lepkowski: *Zeit. anorg. Chem.*, 59, 287, 1908.

The thermoelectric powers of these alloys have been studied by Hutchins [87] and also by Caswell.[88] The curve for the Thomson effect as determined by Laws and also by Caswell is very similar to the curve for the thermoelectric heights. Each curve shows a pronounced maximum when a small quantity of tin is present in the alloy. The curves for electrical and thermal conductivities by Schulze [89] have minima where the preceding curves have maxima. These maxima and minima occur in the region in which the alloys seem to be dilute solid solutions of tin in bismuth. The remainder of the curve for thermal conductivity as well as the curve for electrical conductivity is roughly linear, the form to be expected in alloys which are heterogeneous mixtures. The curve for magnetic susceptibilities has been contributed by Gnesotto and Binghinotto.[90] The addition of tin to bismuth rapidly decreases the diamagnetic susceptibility in the interval where the preceding curves showed either maxima or minima, that is, in the interval of possible solid solutions. The remainder of the curve suggests mechanical mixtures except for the irregularities where the alloys are nearly all tin.

Copper-Zinc.

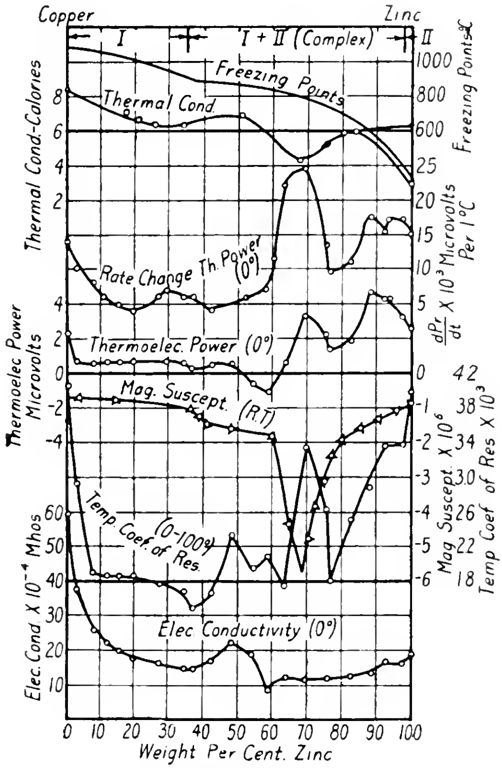
The freezing point curve (Fig. 28) is by Shepherd and others.[91] The structure of this series is complex. Copper dissolves zinc until the concentration of zinc is about 35 per cent. and zinc dissolves copper until the concentration of copper is 2 or 3 per cent. The intermediate alloys may be considered heterogeneous mixtures of two crystalline phases.

The electrical conductivity, the temperature coefficient, the thermoelectric powers and the rate of change of thermoelectric power have been measured by Norsa.[92] Between 0 and about 35 per cent. zinc these curves have the form characteristic of alloys which are solid solutions. The remainder of the curves seem too complicated to admit of analysis in terms of the structure of the alloys. The thermal conductivity is known from the work of Calvert and

[87] Hutchins: *Amer. Jour. Sci.*, **48**, 226, 1894.
[88] Caswell: *Phys. Rev., N. S.*, **12**, 226, 1918.
[89] Schulze: *Ann. d. Phys.*, **9**, 566, 1902.
[90] Gnesotto and Binghinotto: *Inst. Ven.*, **69**, 1382.
[91] Guertler: *Metallographie*, i, 459.
[92] Norsa: *C. R.*, **155**, 348, 1912.

Johnson.[93] The course of this curve is somewhat irregular. The curve for the magnetic susceptibility has been plotted from data by Weber.[94] Between 0 and 35 per cent. zinc it is a straight line.

FIG. 28.



Copper-Tin.

The structure of this series of alloys is complex. The freezing point curve (Fig. 29) by Heycock and Neville[95] gives evidence of one compound Cu_3Sn. Tin is soluble in copper until there is about 13 per cent. copper present. The remainder of the alloys may be considered as mechanical mixtures of two crystalline phases.

The curve for hardness by Kurnakow and Zemczuzny[96] con-

[93] Calvert and Johnson: *Phil. Mag.*, **18**, 354, 1850.

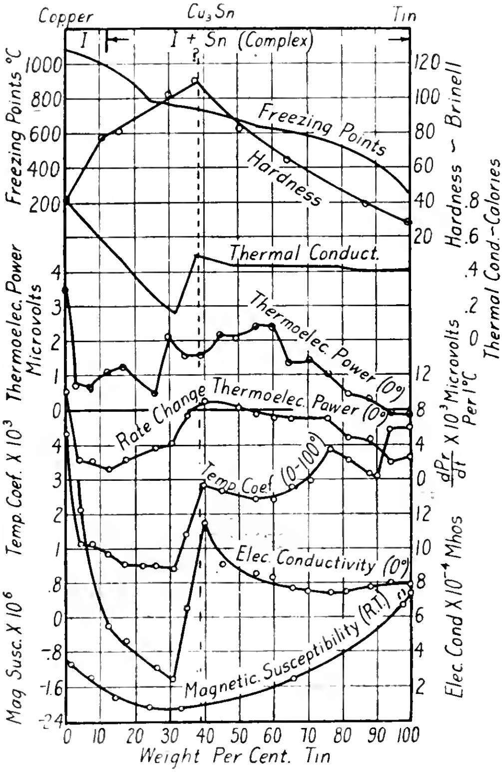
[94] Weber: *Ann. d. Phys.*, **62**, 666, 1920.

[95] Heycock and Neville: *Phil. Trans. A.*, **202**, 1, 1904.

[96] Kurnakow and Zemczuzny: *Zeit. anorg. Chem.*, 60, 9, 1908.

sists of two straight lines and a curve of gentle slope. The two straight lines intersect where the concentration of tin is about 11 per cent. and thus mark the concentration at which tin ceases to be soluble in copper. The intersection of the second straight line with the third portion of the curve marks the concentration for the compound Cu_3Sn. The curves for the electrical conductivity, the

FIG. 29.

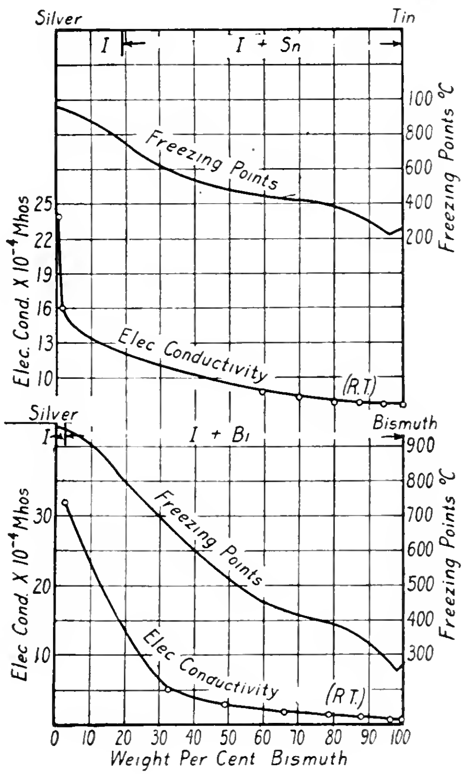


temperature coefficient, the thermoelectric power and its variation with the temperature have been plotted from the observations of Leroux.[97] Between 0 and 35 per cent. tin the curves for electrical conductivities and that for the temperature coefficients are typical of alloys which are solid solutions. Where the solution becomes saturated the direction of the curves suddenly changes. The position of the intermetallic compound is marked on these curves

[97] Leroux: *C. R.*, **155**, 35, 1912.

by cusps. The curve for thermal conductivities is very similar to the curve for electrical conductivities. Wiedemann and Franz's law must, therefore, hold approximately for these alloys. The curve for the magnetic susceptibilities by Clifford [98] does not show the compound, but this is probably due to the fact that the points on the curve near the compound are too far apart.

FIG. 30.



Silver-Tin.

The freezing point curve for silver-tin alloys (Fig. 30) by Petrenko [99] is in complete agreement with the curve obtained by Heycock and Neville. Silver is only slightly soluble in tin and tin is soluble in silver until the concentration of tin is about 18

[98] Clifford: *Phys. Rev.*, 26, 424, 1908.

[99] Petrenko: *Zeit. anorg. Chem.*, 50, 138, 1906; also 53, 200, 1907.

per cent. The other alloys are, therefore, heterogeneous mixtures of two crystalline phases.

The electrical conductivity curve by Matthiessen [100] shows an initial rapid drop for alloys rich in silver. This is characteristic of alloys which are solid solutions. The remainder of the curve has the general shape of curves for a mechanical mixture of two crystalline phases.

Silver-Bismuth.

Petrenko [101] has also given the freezing point curve for silver-bismuth alloys (Fig. 30). It shows a eutectic for alloys containing 2.5 per cent. silver. Under suitable conditions bismuth is somewhat soluble in silver. Most of the alloys are heterogeneous mixtures of a saturated solid solution of bismuth in silver and of bismuth.

The form of the electrical conductivity curve by Matthiessen [102] suggests the formation of solid solutions of bismuth in silver followed by a region in which the alloys are heterogeneous mixtures. The electrical conductivity curve for this series is very similar to the curve for silver-tin alloys. Some observations on thermoelectromotive forces have been made by Battelli.[103]

Lead-Cadmium.

The freezing point curve, according to Stoffel [104] (Fig. 31), consists of two branches meeting at a eutectic for which the temperature is 249° C. Lead and cadmium form a solid solution until the concentration of cadmium is about 5 per cent., at which concentration the solution is saturated. The remainder of the alloys are a mechanical mixture of this saturated solution and cadmium.

The electrical conductivity by Matthiessen [102] is nearly a linear function of the concentration. There are no points on the curve in the region between 95 and 100 per cent. lead in which the solid solutions are now known to be formed.

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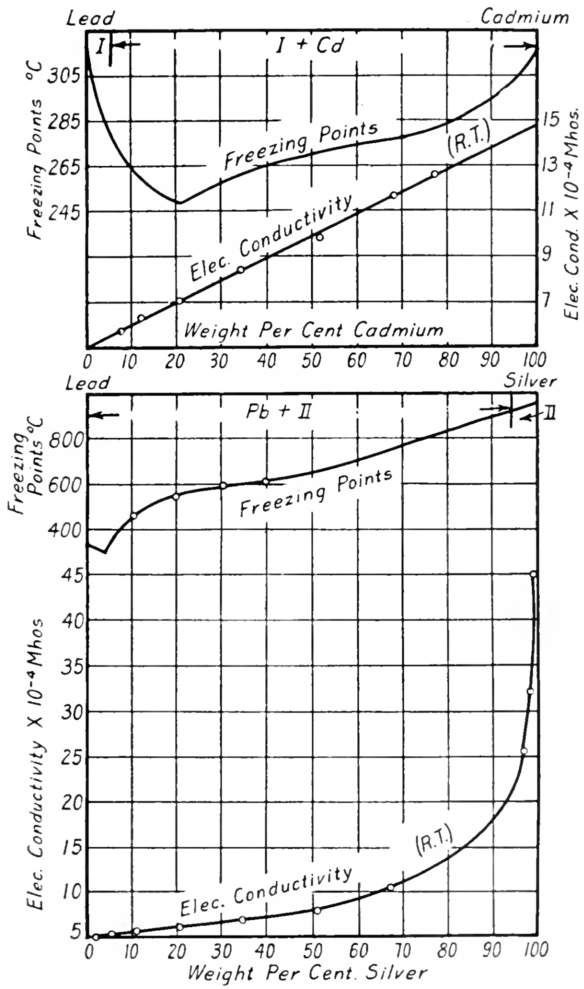
[100] Matthiessen: *Pogg. Ann.*, **110**, 215, 1860.
[101] Petrenko: *Zeit. anorg. Chem.*, **50**, 138, 1906; also **53**, 200, 1907.
[102] Matthiessen: *Pogg. Ann.*, **110**, 208, 1860.
[103] Battelli: *Atti. R. Inst. Ven.* (6), **5**, 1148, 1886.
[104] Stoffel: *Zeit. anorg. Chem.*, **53**, 152, 1907.

Lead-Silver.

The freezing point curve by Petrenko [101] (Fig. 31) shows a eutectic for which the temperature is 303.9° C. Lead is soluble in silver until the alloy contains about 5 per cent. lead. The re-

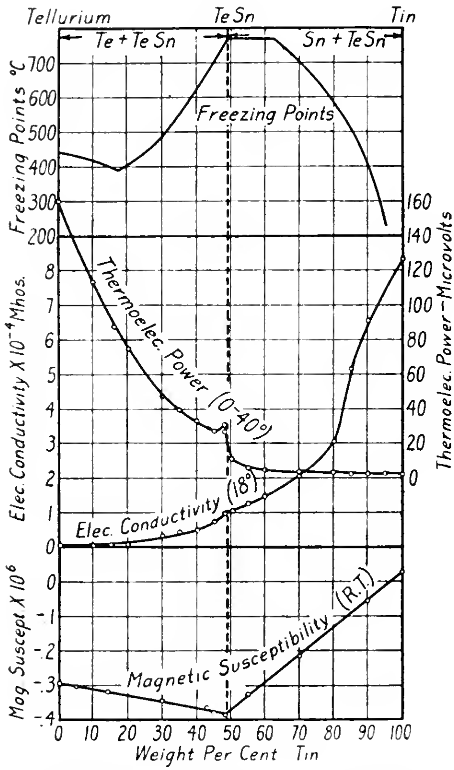
FIG. 31.



mainder of the alloys are heterogeneous mixtures of this solid solution and lead. The structure of these alloys is very similar to the structure of the lead-cadmium alloys.

The curve for electrical conductivities by Matthiessen [105] is very steep between 100 and 97 per cent. silver. This is the region in which a solid solution of lead in silver is formed. For alloys containing less than 50 per cent. silver the curve becomes nearly a straight line, which is characteristic of mechanical mixtures of two crystalline phases.

FIG. 32.



METALS FORMING COMPOUNDS WITH EACH OTHER.

Tellurium-Tin.

The freezing point curve (Fig. 32) by Fay [106] gives the intermetallic compound TeSn, with a eutectic on either side. The results of Kobayashi [107] are in agreement with those of Fay.

[105] Matthiessen: *Pogg. Ann.*, 110, 212, 1860.

[106] Fay: *Jour. Amer. Chem. Soc.*, 29, 1265, 1907.

[107] Kobayashi: *Zeit. anorg. Chem.*, 69, 1, 1911.

Alloys containing less than 48 per cent. tin are mechanical mixtures of tellurium; the compound TeSn and those containing more than 48 per cent. tin are mechanical mixtures of tin and the compound TeSn.

The thermoelectric powers and the electrical conductivities in Fig. 32 are by Haken [108] and the magnetic susceptibilities from the work of Honda and Sone.[109] The compound is indicated on each of the curves. The curve for magnetic susceptibilities consists of two straight lines which intersect at the concentration giving the compound TeSn. One of these straight lines corresponds to mixtures of tellurium and TeSn and the other to mixtures of tin and TeSn. Between 55 and 100 per cent. tin the thermoelectric power curve is a straight line of small slope.

Bismuth-Tellurium.

The freezing point curve of this system (Fig. 33) by Monkemeyer [110] indicates the compound Bi_2Te_3 with a eutectic on either side. Alloys to the left of the compound are mixtures of Bi and Bi_2Te_3 and those to the right are mixtures of Te and the compound Bi_2Te_3.

The thermoelectric power and the electrical conductivity are taken from the observations of Haken,[111] the Hall constant at room temperature from Trabacci [112] and the magnetic susceptibility from the work of Honda and Sone.[113] The presence of the compound is clearly marked on each of the curves. The curve for the Hall constant is very similar to the curve for the thermoelectric powers. A proportionality between the Hall constants and the thermoelectric powers has been recognized by Beattie and these curves are in agreement with the suggestion. Beside the work of Honda and Sone on the diamagnetic susceptibility of these alloys there is some earlier work by Mendenhall and Lent [114] who failed to find in their curve an indication of the compound. Honda and Sone point out that this was probably due to the fact

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[108] Haken: *Ann. d. Phys.*, **32**, 291, 1910.

[109] Honda and Sone: *Sci. Repts. Imp. Univ. Tokio,* **2**, 10, 1913.

[110] Monkemeyer: *Zeit. anorg. Chem.*, **46**, 415, 1905.

[111] Haken: *Ann. d. Phys.*, **32**, 291, 1910.

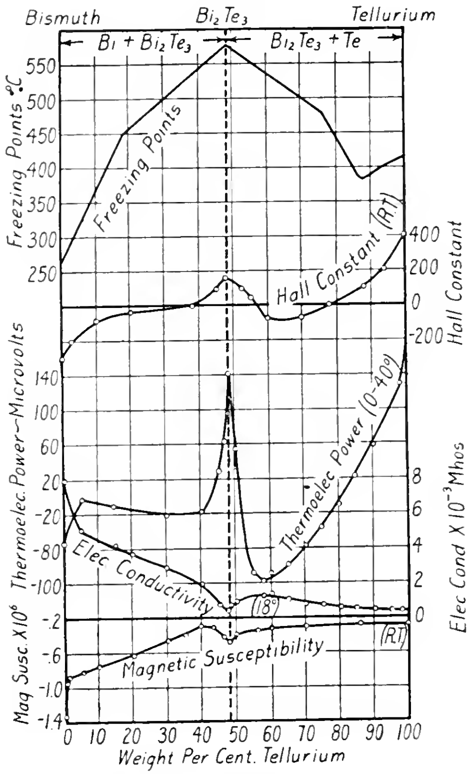
[112] Trabacci: *Nuovo Cim.*, **9**, 95, 1915.

[113] Honda and Sone: *Sci. Repts. Imp. Univ. Tokio,* **2**, 12, 1913.

[114] Mendenhall and Lent: *Phys. Rev.*, **32**, 406, 1911.

that Mendenhall and Lent did not take the points in the neighborhood of the compound close enough together. Between 1 and 41 per cent. tellurium and between 60 and 100 per cent. tellurium the susceptibility curve is nearly a straight line which is characteristic of mechanical mixtures.

FIG. 33.



Bismuth-Magnesium.

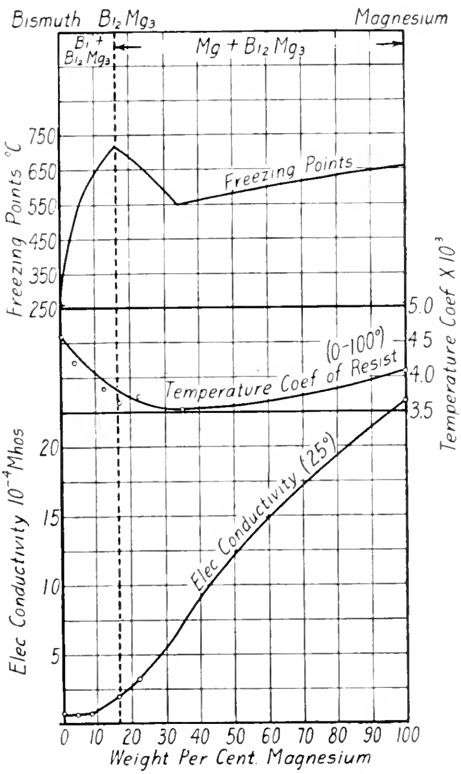
The freezing point curve (Fig. 34) by Grube [115] gives one compound Bi_2Mg_3 and one eutectic for this combination of metals. Another eutectic is probably formed between bismuth and the compound Bi_2Mg_3, but the temperature of this eutectic nearly coincides with the melting point of bismuth. Alloys to the left of the compound consist of heterogeneous mixtures of bismuth

[115] Grube: *Zeit. anorg. Chem.*, 49, 85, 1906.

and the compound Bi_2Mg_3 and those to the right of mixtures of magnesium with the compound Bi_2Mg_3.

The electrical conductivity and the average temperature coefficient have been determined by Stepanow.[116] Neither of these curves show the presence of the compound Bi_2Mg_3. This may be due to the fact that the points in the neighborhood of this

FIG. 34.



compound were not taken sufficiently close together. The course of the curves on either side of the compound somewhat resembles straight lines, indicating that the alloys on the two sides of the compound are mechanical mixtures.

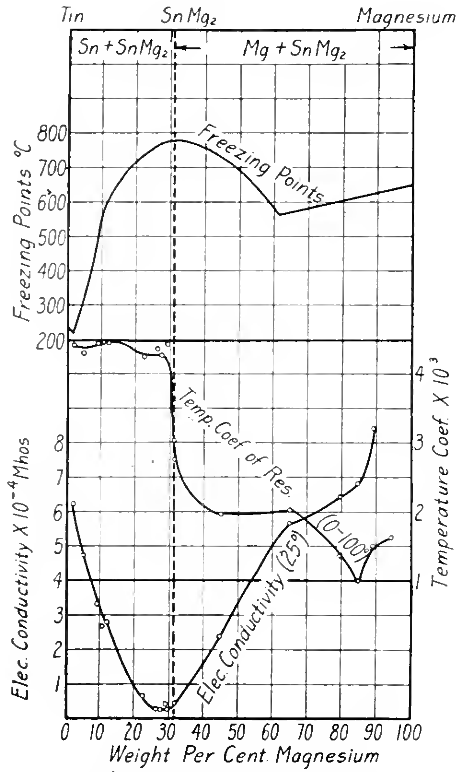
Magnesium-Tin.

The equilibrium diagram for magnesium and tin shows one

[116] Stepanow: *Zeit. anorg. Chem.*, **78**, 1, 1912.

intermetallic compound, Mg_2Sn. There is a eutectic on either side of this compound. The freezing point curve of Fig. 35 is by Grube.[117] Magnesium does not seem to be soluble in tin, but Grube finds that magnesium dissolves about 6 per cent. of tin. With the exception of alloys in this region, the alloys of this series are mechanical mixtures of two crystalline phases.

FIG. 35.

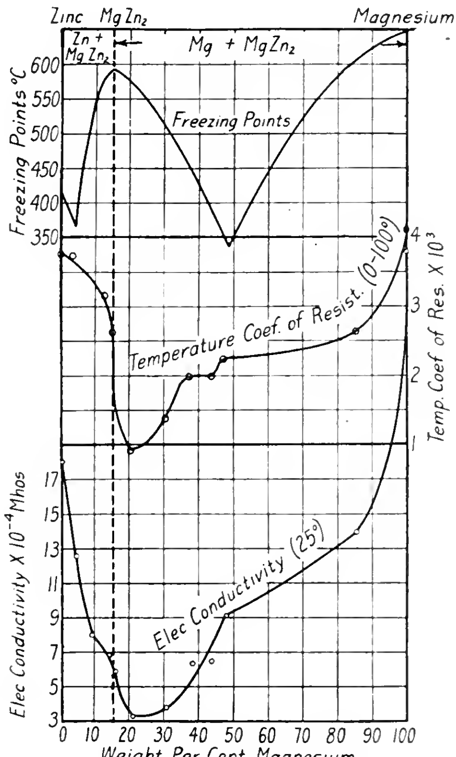


The electrical conductivities and the temperature coefficients of the resistance are known from the work of Stepanow.[116] The addition of tin to magnesium causes a rapid drop in the electrical conductivity and the temperature coefficient. The steepness of these curves for large concentrations of magnesium confirms the existence of solid solutions of magnesium and tin where the concentration of tin is small. The compound is marked by a rapid

[117] Grube: *Zeit. anorg. Chem.*, 46, 1905.

drop in the temperature coefficient and a minimum in the electrical conductivity. Between 0 and about 28 per cent. and between 40 and 65 per cent. magnesium the temperature coefficient is nearly constant. This constancy could be inferred from the fact that the alloys over these regions are mechanical mixtures, in the former case of tin and the compound $SnMg_2$ and in the latter case of the

FIG. 36.



compound $SnMg_2$ and a saturated solid solution of magnesium and tin.

Magnesium-Zinc.

These two metals, according to Grube,[118] from whose work the freezing point curve of Fig. 36 is taken, form one intermetallic compound with the formula $MgZn_2$. On either side of

[118] Grubé: *Zeit. anorg. Chem.*, 49, 80, 1906.

this compound is a eutectic and the alloys to the left of the compound may be regarded as heterogeneous mixtures of zinc and the compound $MgZn_2$ and those to the right of the compound, mixtures of magnesium and the compound $MgZn_2$. It seems possible that zinc may form dilute solid solutions with magnesium.

The electrical conductivities and the temperature coefficients of the resistance are from the observations of Stepanow.[119] These curves are similar in form to the corresponding curves for magnesium-tin alloys. In the region where the concentration of zinc is small and dilute solid solutions of zinc in magnesium may be formed both of these curves are steep, especially the curve of electrical conductivities. The position of the compound is marked by a rapid decrease in both the temperature coefficient and the electrical conductivity.

Bismuth-Thallium.

The freezing point curve by Chickashige[120] (Fig. 37) indicates a compound at the concentration corresponding to Bi_5Tl_3 with a eutectic on either side of it. The freezing point curve seems to have three maxima, but only one of them corresponds to a simple atomic ratio, and that is the one giving the compound Bi_5Tl_3. A micrographic examination also locates a compound in this neighborhood.

The electrical conductivity curve for these alloys are by Whitford[121] and the magnetic susceptibilities by Mendenhall and Lent.[122] Both the electrical conductivity and the magnetic susceptibility were measured at room temperature. The presence of the intermetallic compound is clearly indicated on both of these curves.

Aluminium-Magnesium.

Grube[123] whose freezing point curve is reproduced in Fig. 38 finds one maximum which corresponds to either Al_2Mg_3 or Al_3Mg_4. These compounds lie so close together that it is difficult to choose between them, but Grube concludes that Al_3Mg_4 is the more prob-

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[119] Stepanow: *Zeit. anorg. Chem.*, **78**, 25, 1912.

[120] Chickashige: *Zeit. anorg. Chem.*, **51**, 328, 1906.

[121] Whitford: *Phys. Rev.*, **35**, 144, 1912.

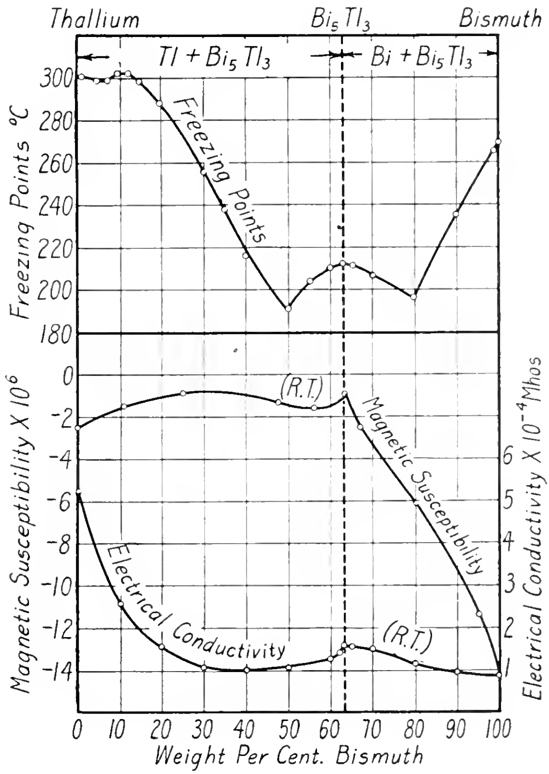
[122] Mendenhall and Lent: *Phys. Rev.*, **32**, 415, 1911.

[123] Grube: *Zeit. anorg. Chem.*, **45**, 225, 1905.

able. To the right of this compound the alloys may be considered mechanical mixtures of Mg and the compound Al_3Mg_4 and for lower concentrations of magnesium they are mechanical mixtures of aluminium and the compound Al_3Mg_4.

Besides the observations of Broniewski [124] from which the

FIG. 37.



curves in Fig. 38 have been plotted there are observations by Pecheux [125] on the thermoelectromotive forces of some members of this series. According to the interpretation of Broniewski, two compounds are indicated by his curves: *viz.*, AlMg and Al_2Mg_3. Of these compounds Al_2Mg_3 is much more clearly marked than the compound AlMg.

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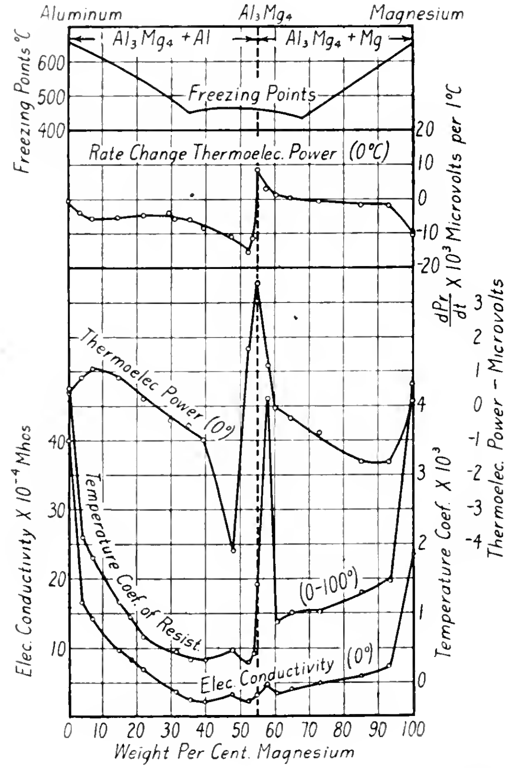
[124] Broniewski: *Ann. de Phys. et Chem.* (8), 25, 76, 1912.

[125] Pecheux: *C. R.*, 139, 1202, 1904.

Copper-Arsenic.

The freezing point curve of Fig. 39 is by Friedrich.[126] From the equilibrium diagram and from a metallographic study of these alloys it is found that copper and arsenic form two compounds Cu_3As and Cu_3As_2 and that arsenic dissolves in copper up to 4 per cent.

FIG. 38.



Some observations on the electrical conductivity of copper-arsenic alloys have been made by Matthiessen and Holtzmann[127] and later by Hampe.[128] Friedrich also gives some data on the electrical resistance of these alloys for low concentrations of arsenic. The specific resistance of these alloys and the tempera-

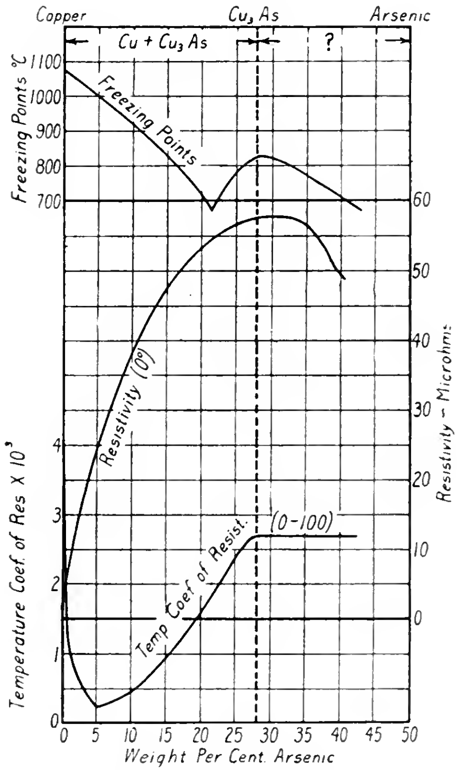
[126] Friedrich: *Metallurgie*, **5**, 529, 1908.

[127] Matthiessen and Holtzmann: *Pogg. Ann.*, **110**, 229, 1860.

[128] Hampe: *Chemiker, Ztg.*, **726**, 1892.

ture coefficient (Fig. 39) are the values given by Puschin and Dischler.[129] The electrical resistance of copper is much increased by the addition of small quantities of arsenic, and the temperature coefficient is decreased. This occurs in the region where a solid solution of arsenic in copper is formed and is characteristic of the formation of such solutions. When the concentration of arsenic is about 28.5 per cent. the specific resistance has its maximum

FIG. 39.



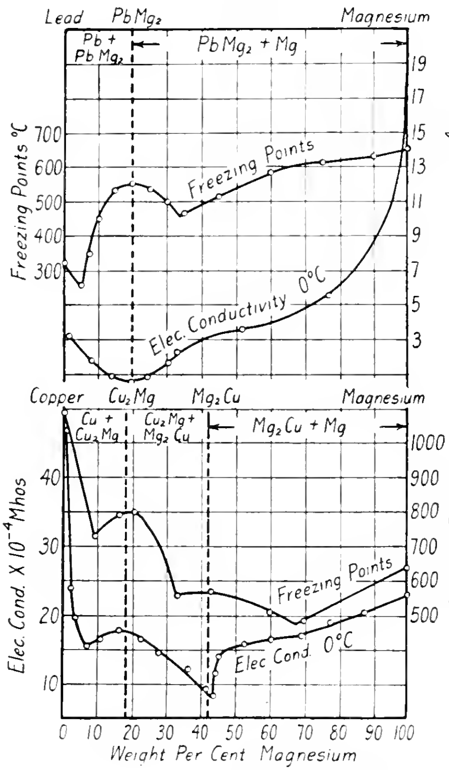
value. This maximum value comes at the concentration for the compound Cu_3As. The temperature coefficient decreases from its value in pure copper, passes through a minimum for 6 per cent. arsenic and then increases until the concentration corresponding to the compound Cu_3As is reached. Beyond this concentration the temperature coefficient remains nearly constant.

[129] Puschin and Dischler: *Zeit. anorg. Chem.*, 80, 65, 1913.

Lead-Magnesium.

The freezing point curve [130] (Fig. 40) shows a maximum corresponding to the compound Mg_2Pb with a eutectic on either side. For concentrations of magnesium less than that corresponding to the compound the alloys are heterogeneous mixtures of lead and

FIG. 40.



Mg_2Pb and for greater concentrations they are mixtures of the compound Mg_2Pb and magnesium.

The curve for electrical conductivities by Stepanow [131] (Fig. 40) shows that the electrical conductivity decreases rapidly with the addition of lead to magnesium until the alloy contains about 5 per cent. lead. At the concentration corresponding to the compound Mg_2Pb the electrical conductivity passes through a minimum.

[130] Grube: *Zeit. anorg. Chem.*, 44, 117, 1905.

[131] Stepanow: *Zeit. anorg. Chem.*, 78, 12, 1912.

Magnesium-Copper.

The freezing point curve (Fig. 40) as determined by Urasow [132] and also Sahem [133] shows two maxima corresponding to the intermetallic compounds Cu_2Mg and $CuMg_2$. There are, therefore, in the equilibrium four types of crystalline substances to be considered: Cu, Cu_2Mg, $CuMg_2$ and Mg. None of these substances seems able to form solid solutions with any of the others. The alloys then become divided into three groups, mixtures of Cu with Cu_2Mg; mixtures of Cu_2Mg with $CuMg_2$ and mixtures of Mg and $CuMg_2$.

The electrical conductivity has been measured by Stepanow.[134] He also gives data from which the temperature coefficient can be calculated. These data are, however, very irregular and have not been plotted. Between 100 and 45 per cent. magnesium the curve is nearly a straight line, as it should be for a mechanical mixture of Mg and $CuMg_2$. Between 43 and 20 per cent. magnesium it is again a straight line corresponding to the mixture of $CuMg_2$ and Cu_2Mg. The early part of the curve for small concentrations of magnesium is steep and suggests a solid solution rather than a mechanical mixture.

Antimony-Tellurium.

The freezing point curve of this series by Fay and Ashley [135] (Fig. 41) gives a maximum corresponding to the compound Sb_2Te_3. There is also a eutectic for which the temperature is 421° C. The compound forms a continuous series of mixed crystals with antimony but does not mix in the same way with pure tellurium.

The electrical conductivity and the thermoelectric power for this series have been measured by Haken.[136] The addition of tellurium to antimony causes a rapid decrease in both the electrical conductivity and the thermoelectric power. Both of these quantities pass through a minimum and rise rapidly to their value for the compound Sb_2Te_3. The course of these curves between 0 and 60 per cent. tellurium is typical of alloys formed of two crystalline

[132] Urasow: *Jour. russ. Chem. Ges.*, 39, 1566, 1909.

[133] Sahem: *Zeit. anorg. Chem.*, 57, 3, 1908.

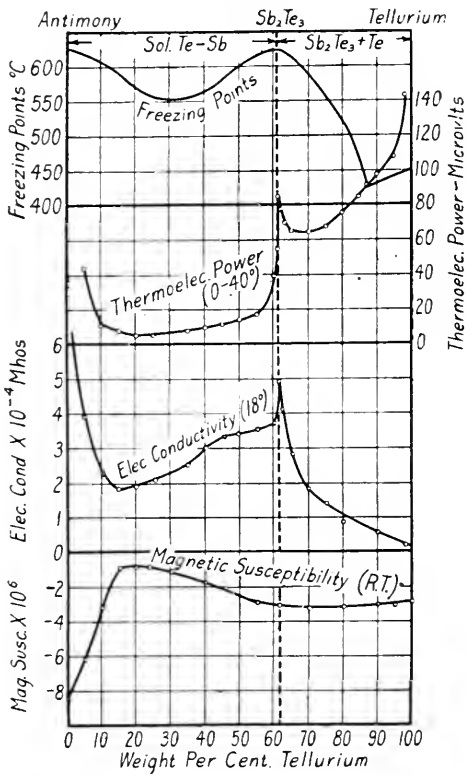
[134] Stepanow: *Zeit. anorg. Chem.*, 78, 20, 1912.

[135] Fay and Ashley: *Amer. Chem. Jour.*, 27, 1902.

[136] Haken: *Ann. d. Phys.*, 32, 291, 1910.

phases, forming solid solutions. The compound is clearly marked on both curves. The magnetic susceptibility of these alloys has been studied by Honda.[137] Between 100 and 62 per cent. tellurium the curve is nearly a straight line. Over this region the susceptibility varies little. The compound is marked by a sudden change in the direction of the curve at the concentration of the compound.

FIG. 41.



Antimony-Aluminium.

The freezing point curve (Fig. 42) by Gautier[138] has two maxima. One corresponds to the compound AlSb, but the existence of a second compound is questioned.

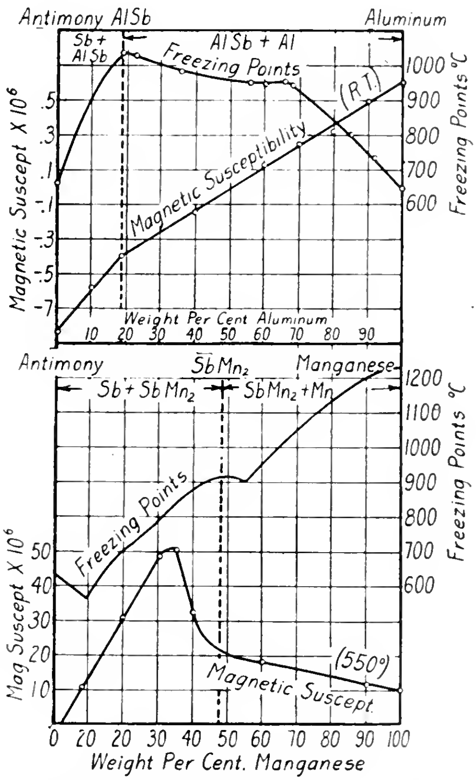
The diamagnetic susceptibility of these alloys has been con-

[137] Honda: *Sci. Rept. Imp. Univ. Tokio*, **2**, 9, 1913.

[138] Gautier: "Contribution a l'etude des alleages," **112**, 1901.

tributed by Honda.[139] The curve showing the susceptibility as a function of the concentration is made up of two straight lines which intersect where the alloy contains 18.4 per cent. aluminium, *i.e.*, at the concentration for the compound AlSb. The character of the susceptibility curve indicates that alloys containing less than 18.4 per cent. aluminium are mechanical mixtures of anti-

FIG. 42.



mony and the compound AlSb, and those containing more than 18.4 per cent. aluminium are mixtures of aluminium and the compound AlSb.

Antimony-Manganese.

The compound $SbMn_2$ is indicated on the freezing point curve (Fig. 42) by Williams.[140] Between 100 and about 52 per cent.

[139] Honda: *Sci. Rept. Imp. Univ. Tokio*, **2**, 9, 1913.

[140] Williams: *Zeit. anorg. Chem.*, **55**, 1, 1907.

manganese the alloys are heterogeneous mixtures of Mn and the compound $SbMn_2$; between 0 and about 31 per cent. manganese they are a mixture of antimony and a secondary crystalline phase.

The thermal and electrical properties of these alloys have not been studied. The magnetic susceptibility at 550° C. has been determined by Honda.[139] His observations were made with a field of 10.9 kilogausses. The susceptibility for this temperature is nearly independent of the temperature. From 0 to 31.2 per cent. manganese the susceptibility is nearly a linear function of the concentration. In this region the alloys are mechanical mixtures of Sb and $SbMn_2$. Between 31.2 and 40.7 per cent. manganese the character of the susceptibility curve changes because a new crystalline phase appears. Between 40.7 and 47.8 per cent. Mn there is another straight line portion, followed by another linear portion from 50.5 to 100 per cent. Mn, the region over which the alloys are heterogeneous mixtures of manganese and a second crystalline phase.

Antimony-Zinc.

The freezing point curve for this series as determined by Monkmeyer [141] (Fig. 43) has two maxima, one corresponding to the compound SbZn and the other to the compound Sb_3Zn_2. The alloys divide themselves into three groups—heterogeneous mixtures of Zn and Sb_3Zn_2, mixtures of Sb_3Zn_2 and SbZn and mixtures of SbZn and Sb. The structure of the series of alloys is very similar to the structure of the antimony-cadmium series.

The curve for the magnetic susceptibilities by Honda [142] consists essentially of two straight lines intersecting at the concentration for the compound SbZn. Over the region where there is supposed to be a mixture of Sb_3Zn_2 and SbZn the curve departs somewhat from a straight line. The linear relation between the susceptibility and the concentration confirms the existence of the mechanical mixtures indicated by thermal analysis. The curves for the specific resistance, the thermoelectric power and the Hall constant [143] show clearly the compound SbZn, but they give no evidence of the compound Sb_3Zn_2.

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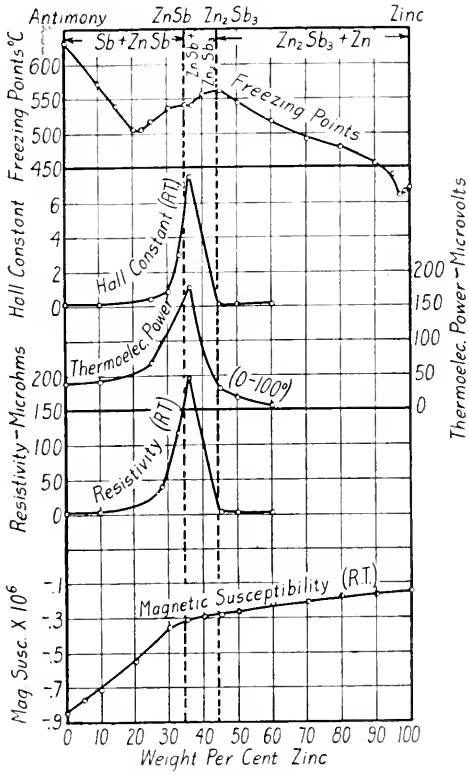
[141] Monkmeyer: *Zeit. anorg. Chem.*, **43**, 182, 1905.
[142] Honda: *Sci. Rept. Imp. Univ. Tokio*, **2**, 6, 1913.
[143] Smith: *Phys. Rev.*, **32**, 178, 1911.

Antimony-Cadmium.

The freezing point curve (Fig. 44) by Treitschke [144] gives a compound SbCd which is stable and another Sb_2Cd_3 which is probably unstable. Between 0 and about 40 per cent. antimony the alloys are mixtures of Cd and Sb_2Cd_3; between 40 and 52 per

FIG. 43.



cent. mixtures of SbCd and Sb_2Cd_3 and between 52 and 100 per cent. mixtures of SbCd and Sb.

The curves for the specific resistance, temperature coefficient and thermal conductivity are from the observations of Eucken and Gehlhoff.[145]

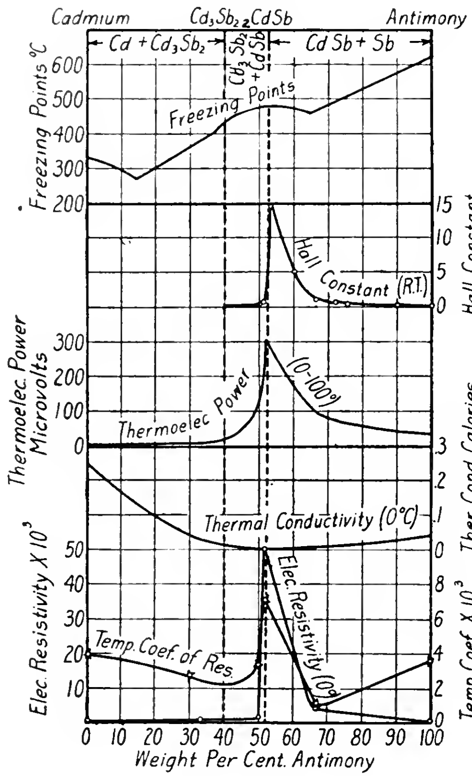
The thermoelectric power of this series has been frequently studied. The curve of thermoelectric powers in Fig. 44 is from

[144] Treitschke: *Zeit. anorg. Chem.*, 50, 217, 1906.

[145] Eucken and Gehlhoff: *Verh. d. deut. Phys. Ges.*, 169, 1912.

Haken.[146] The Hall constant is by the author.[147] The position of the compound is very evident on all of these curves except the curve for the thermal conductivities. On either side of this compound and at some distance from the concentration at which it appears neither the resistance, nor the thermoelectric power, nor

FIG. 44.



the Hall constant changes rapidly with a change in the composition of the alloys.

Magnesium-Silver.

The freezing point curve[148] (Fig. 45) gives one maximum at the concentration for the compound MgAg. There is probably a second compound Mg_3Ag. Between 0 and 8.5 per cent. magnesium

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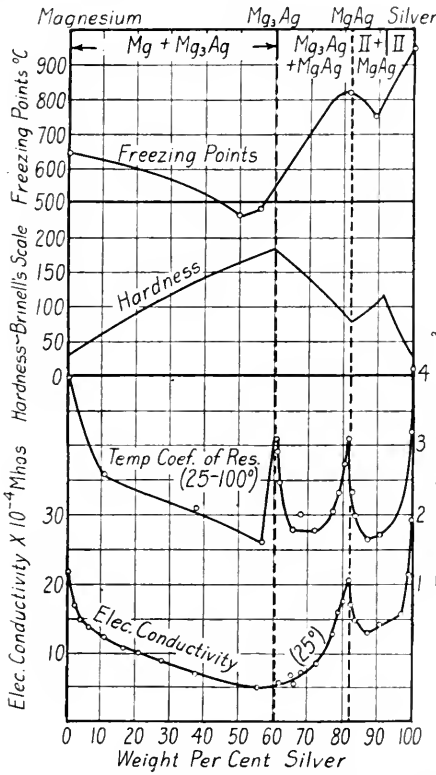
[146] Haken: *Ann. d. Phys.*, 32, 291, 1910.

[147] Smith: *Phys. Rev.*, 32, 178, 1911.

[148] Zemczuzny: *Zeit. anorg. Chem.*, 49, 403, 1906.

there is a solid solution of magnesium in silver followed by a mechanical mixture of this solid solution and the compound MgAg. There then follows a region in which there is a mixture of Mg_3Ag and MgAg. Between 0 and 60 per cent. silver the alloys are mixtures of Mg and Mg_3Ag.

FIG. 45.

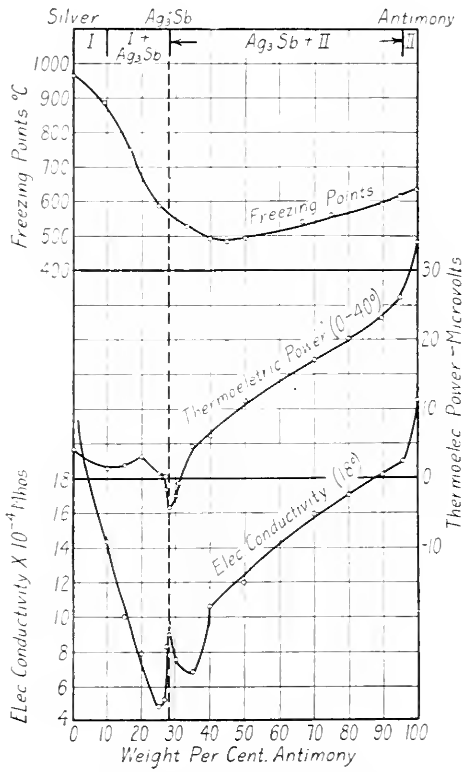


The curve for the hardness [149] of these alloys shows these regions quite clearly. It is made up of four straight lines. One of these lines extends from 0 to 60 per cent. silver, over the region in which the alloys are mechanical mixtures of Mg and Mg_3Ag; the next from 60 to 82 per cent. silver where there is a mixture of MgAg and Mg_3Ag; the third one from 82 to 91 per cent. silver where there is a mixture of MgAg and a saturated solid solution of magnesium in silver; the last from 91 to 100 per cent. silver, the region of the solid solutions of magnesium in silver. The

[149] Desch: "Intermetallic Compounds," p. 15.

curves for the electrical conductivity and the temperature coefficient are by Smirnow and Kurnakow.[150] The positions of both compounds are marked on these curves. The initial rapid decrease in the electrical conductivity and the temperature coefficient for fairly

FIG. 46.



small concentrations of magnesium in silver is in agreement with the conception that solid solutions are formed over this interval. The nearly linear course of these curves between 10 and 58 per cent. silver follows from the fact that the alloys are mechanical mixtures of two crystalline phases over this interval.

Silver-Antimony.

Petrenko [151] gives the freezing point curve (Fig. 46). By a sudden change in curvature it suggests the compound Ag_3Sb. A

[150] Smirnow and Kurnakow: *Zeit. anorg. Chem.*, **72**, 31, 1911.

[151] Petrenko: *Zeit. anorg. Chem.*, **50**, 1906.

solid solution of silver in antimony is formed until the concentration of the silver becomes about 4 per cent. and a solid solution of antimony in silver until the concentration of antimony is about 10 per cent. Between about 10 and 28 per cent. antimony there is a mechanical mixture of Ag_3Sb and a saturated solid solution of antimony in silver and between 28 and 96 per cent. a mixture of Ag_3Sb and a saturated solution of silver in antimony.

The curve for the thermoelectric heights as well as that for the electrical conductivities has been worked out by Haken,[152] and these curves are reproduced in Fig. 46. The compound is clearly indicated and the region in which silver is soluble in antimony is marked by the steepness of both curves in this region. In like manner the interval in which antimony is soluble in silver is indicated by the characteristic drop in the electrical conductivity. The decrease in the thermoelectric power for small concentrations of antimony is less marked.

Aluminium-Copper.

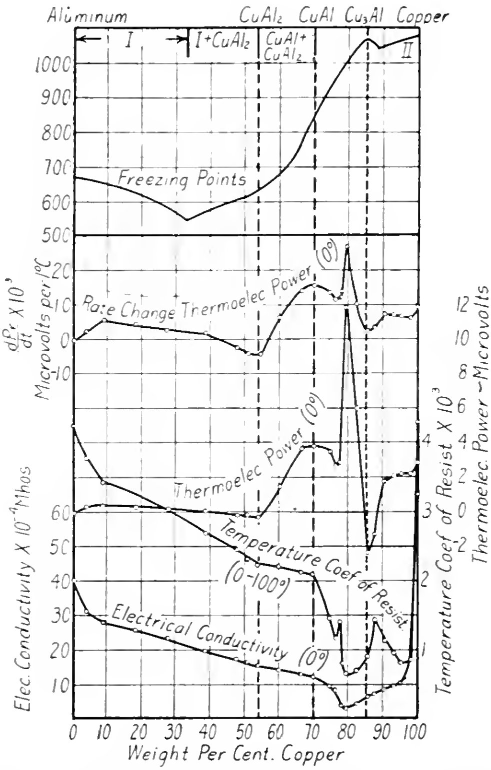
By thermal analysis Gwyer[153] finds evidence of three compounds: Al_2Cu, AlCu and $AlCu_3$ (Fig. 47). The compound Al_2Cu is decomposed before fusion. Between 0 and 9 per cent. copper there are solid solutions of aluminium in copper, followed by a region of mixed crystals of Cu_3Al and CuAl; a second region of mixtures of CuAl and $CuAl_2$, and a third region of mixtures of $CuAl_2$ and a saturated solution of copper in aluminium.

A number of observations have been made on the electrical properties of these alloys. Among the earlier observations in this region are those made by LeChatelier,[154] Dewar and Flemming,[155] Battelli,[156] Steinmann,[157] Pouchine[158] and Pecheux.[159] The curves in Fig. 47 have been plotted from the data given by Broniewski.[160] On the curve for electrical conductivity and also on the one for the temperature coefficient the three compounds are indicated by a

[152] Haken: *Ann. d. Phys.*, **32**, 291, 1910.
[153] Gwyer: *Zeit. anorg. Chem.*, **57**, 113, 1908.
[154] LeChatelier: *C. R.*, **101**, 454, 1890.
[155] Dewar and Flemming: *Phil. Mag.* (5), **36**, 271, 1893.
[156] Battelli: *Atti. R. Inst. Veneti.* (6), **5**, 1148, 1886–7.
[157] Steinmann: *C. R.*, **130**, 1300, 1900.
[158] Pouchine: *Jour. Soc. phys. Chem. russ.*, **39**, 528, 1907.
[159] Pecheux: *C. R.*, **148**, 1041, 1909.
[160] Broniewski: *Ann. de Phys. et Chem.* (8), **25**, 91, 1912.

change in the slope of the curves at the concentrations corresponding to the compounds. On the curve for the thermoelectric power and also on the curve for the variations of the thermoelectric power with the temperature the compounds Al_2Cu and $AlCu_3$ are marked by minima in the curves. Over the region between 91 and 100 per cent. copper where solid solutions of aluminium in copper

FIG. 47.



are formed the electrical conductivity and the temperature coefficient show the decreases characteristic of such solutions.

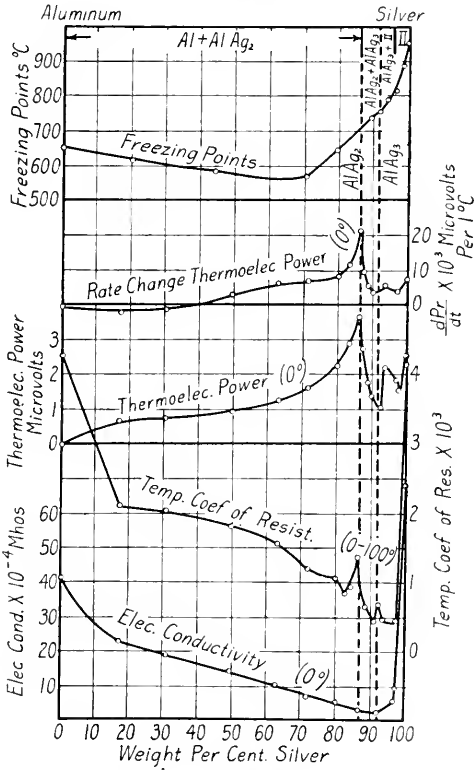
Aluminium-Silver.

The freezing point curve (Fig. 48) by Petrenko[161] gives two compounds, $AlAg_2$ and $AlAg_3$. These compounds are indicated by a change in the curvature of the freezing point curve at the concentration at which the compound occurs. This change in curvature is

[161] Petrenko: *Zeit. anorg. Chem.*, 46, 49, 1905.

not very evident from the curve as plotted in Fig. 48. Between 0 and 87.5 per cent. silver the alloys are mechanical mixtures of aluminium and the compound $AlAg_2$; between 87.5 and 91.5 per cent. silver mixed crystals of $AlAg_2$ and $AlAg_3$; between 91.5 and 94 per cent. silver mixtures of $AlAg_3$ and saturated solid solutions of

FIG. 48.



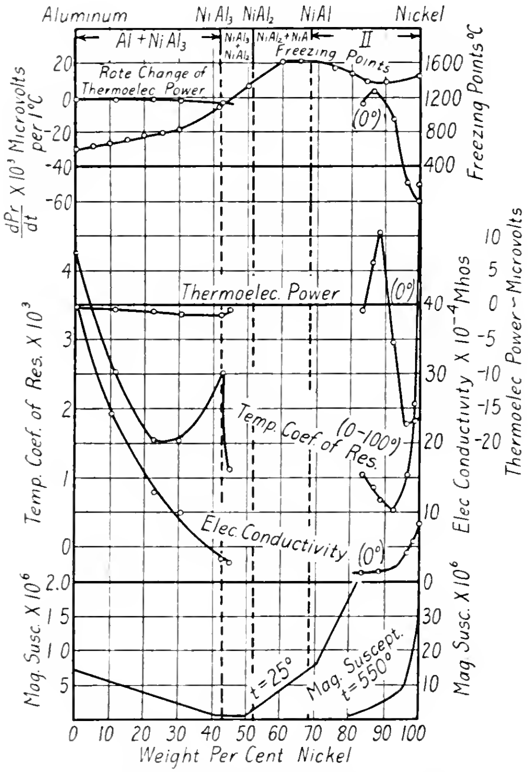
aluminium in silver, and between 94 and 100 per cent. silver solid solutions of aluminium in silver.

The curves for the electrical conductivity, temperature coefficient, thermoelectric power and variations of the thermoelectric power with the temperature have been taken from the observations of Broniewski.[162] The compound $AlAg_2$ is marked clearly by a peak in each of the curves except the curve for the electrical conductivity where the peak is small. On the other hand, a

[162] Broniewski: *Ann. de Phys. et Chem.* (8), **25**, 83, 1912.

minimum occurs in each of the curves except the curve for electrical conductivities where the concentration corresponds to the compound $AlAg_3$. Except for the two peaks in the curve for the temperature coefficient that curve as well as the curve for electrical conductivities has the form which is found in binary alloys

FIG. 49.



of metals which form limited solid solutions with each other and then these solid solutions mix mechanically to form the remainder of the alloys of the series.

Aluminium-Nickel.

The freezing point curve (Fig. 49) by Gwyer [163] gives a maximum near the concentration corresponding to the compound NiAl. Between 0 and 42 per cent. nickel the alloys are mixtures of Al

[163] Gwyer: *Zeit. anorg. Chem.*, 57, 133, 1908.

and $NiAl_3$; between 42 and 52 per cent. nickel mixtures of $NiAl_3$ and $NiAl_2$; between 52 and 68 per cent. nickel mixtures of $NiAl_2$ and NiAl, and between 68 and 100 per cent. nickel an unsaturated solution of aluminium in nickel.

The electrical conductivity, the temperature coefficient, the thermoelectric power and its variation with the temperature have been plotted from the observations of Broniewski.[164] In the interval between 45 and 84 per cent. nickel there are no observations on account of the brittleness of the alloys in this region. The compound $NiAl_3$ is indicated by a peak on the temperature coefficient curve. The magnetic susceptibilities by Honda [165] have been measured at 25° C. for alloys containing less than 80 per cent. nickel. For alloys containing more than 80 per cent. nickel the susceptibilities were determined at 550° C. A magnetic field of from 5 to 12 kilogausses was used. Until the alloys contain 80 per cent. nickel the susceptibility curve consists of four straight lines intersecting at the concentrations at which a new crystalline phase appears.

Nickel-Tin.

The composition of this series of alloys is very complex. The freezing point curve by Gautier [166] has been reproduced in Fig. 50. Five different kinds of crystals are present in the solidified alloys.

No observations have been found on the thermal and electrical properties of these alloys. The magnetic properties have been studied by Honda.[165] On the alloys containing less than 60 per cent. nickel the observations were made at 25° C. On the remainder of the alloys the observations were made at 550° C.—a temperature above the transformation point. The external magnetic field was from 5 to 12 kilogausses. The ferro-magnetic properties disappear when the concentrations of the constituents correspond to the compound Ni_3Sn. So long as the alloys are composed of the same two kinds of crystals in varying concentrations the susceptibility is a linear function of the concentration. Where one type of crystal disappears and is replaced by another the slope of the curve suddenly changes.

[164] Broniewski: *Ann. de Chem. et Phys.* (8), **25**, 108, 1912.

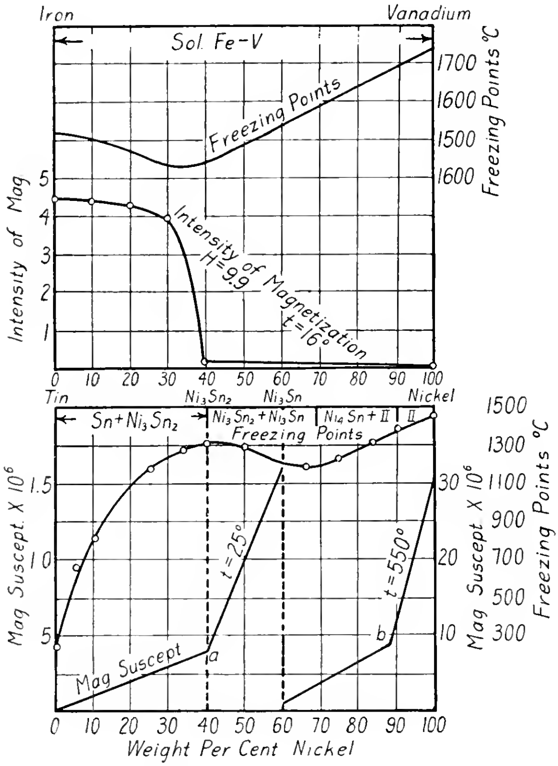
[165] Honda: *Ann. d. Phys.*, **32**, 1015, 1910.

[166] Gautier: *C. R.*, **122**, 109.

Iron-Vanadium.

The composition of iron and vanadium alloys has been studied by Vogel and Tammann,[167] and it has been found that they solidify in the form of an unbroken series of mixed crystals. The freezing point curve (Fig. 50) has a minimum in the neighborhood of 35 per cent. vanadium.

FIG. 50.



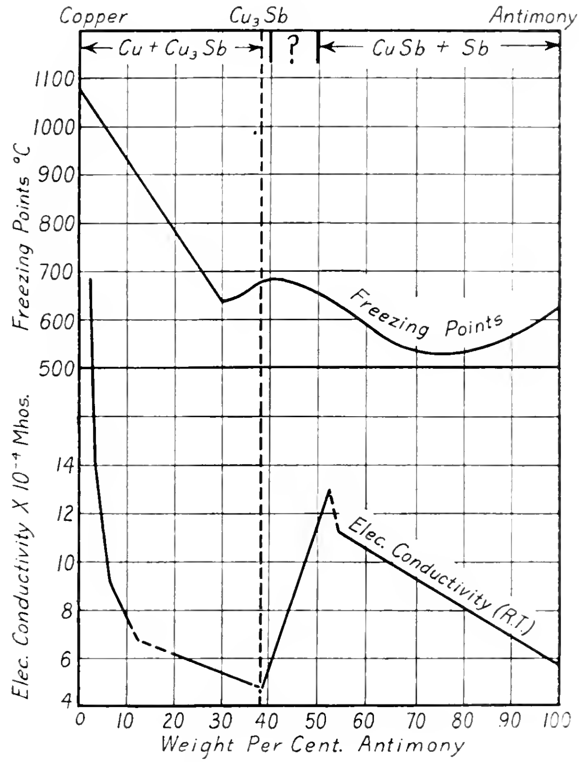
The electrical and thermal properties of this series of alloys do not seem to have been studied. There are observations by Honda[168] on the intensity of magnetization. These observations were made at 16° C. and with a magnetic field of 9.9 gausses. The intensity of magnetization of iron decreases slowly with an increasing concentration of vanadium until that concentration is

[167] Vogel and Tammann: *Zeit. anorg. Chem.*, **58**, 79, 1908.

[168] Honda: *Ann. d. Phys.*, **32**, 1910, 1912.

reached at which the freezing point curve has its minimum. Here there is an extraordinarily rapid decrease in the intensity of magnetization so that an alloy containing more than 40 per cent. of vanadium is very feebly magnetic.

FIG. 51.



Copper-Antimony.

Baikow[169] has given a complete equilibrium diagram from which the freezing point curve (Fig. 51) is taken. The compound Cu_3Sb is formed. Alloys to the right or left of this compound are heterogeneous mixtures of two crystalline phases. Copper, according to Stead, dissolves about 0.3 per cent. antimony.

For small concentrations of antimony the electrical conductivity curve by Matthiessen[170] is very steep. This is in the region

[169] Baikow: *Jour. reiss. Phys. Chem. Ges.*, 36, 111, 1904.
[170] Matthiessen: *Pogg. Ann.*, 110, 100, 1860.

where antimony and copper form dilute solid solutions. The electrical conductivity curve shows a sudden change in direction where the concentrations correspond to the compound Cu_3Sb. Between 55 and 100 per cent. antimony the conductivity curve is a straight line. Over this interval the alloys are mechanical mixtures. A third region of mechanical mixtures is indicated by the straight line representing the electrical conductivity between 38.4 and 52 per cent. antimony.

CHANGE OF THERMOELECTROMOTIVE FORCE WITH TEMPERATURE.

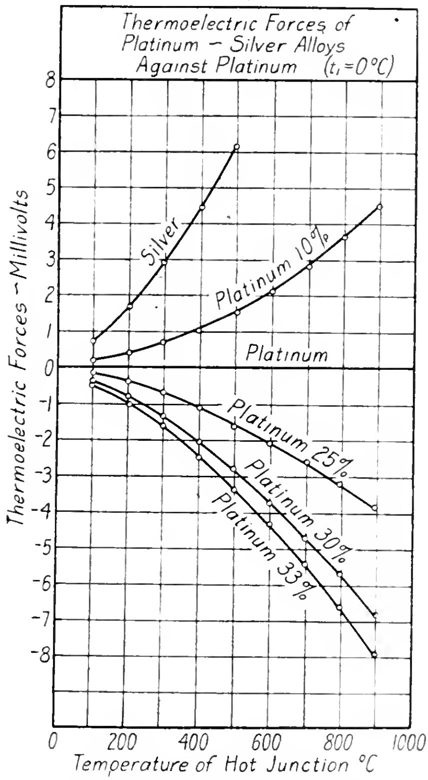
The rate of variation of the thermoelectromotive force with the temperature for a large number of aluminium alloys has already been discussed. The observations on these alloys were made by Broniewski. In his work the observations were extended over a limited range of temperature. The most important work in this connection is that of Giebel,[171] in which the observations were extended over a large range of temperature. He studied the following series of alloys: Palladium-gold, palladium-platinum, palladium-silver, platinum-silver, platinum-rhodium, and platinum-iridium. The thermoelectromotive forces were measured against platinum in this case and the temperature of the cold junction was kept at 0° C. Observations were made at intervals of 100° C. between 0° and 900° C. The observed thermoelectromotive forces have been plotted against the temperatures in Figs. 52, 53 and 54. From Figs. 52 and 54 it is seen that the higher the temperature the more rapid is the rate of change of the thermoelectromotive force with the temperature for palladium-silver and for platinum-silver alloys. In the palladium-platinum series (Fig. 53) there is nearly a linear relation between the thermoelectromotive force and the temperature after the alloy contains about 40 per cent. platinum. When the concentration of platinum is increased above 40 per cent. this linear relation is more nearly realized.

In Fig. 55 the thermoelectromotive force in platinum-rhodium alloy at a particular temperature has been plotted against the concentration of rhodium in the alloy. These curves show that the thermoelectromotive force increases rapidly with the increase in the concentration of rhodium until the alloy contains about 5 per cent rhodium. Between 5 and 10 per cent. rhodium the increase is much less rapid, especially at low temperatures. Increasing the

[171] Giebel: *Zeit. anorg. Chem.*, 69, 38, 1910, and 70, 240, 1911.

concentration of rhodium beyond 10 per cent. changes only slightly the thermoelectromotive force until the temperature of the hot junction exceeds 1000° C. At very high temperatures the thermoelectromotive force continues to increase with increasing concentration of rhodium, but this rate of increase decreases with increasing concentration of rhodium.

FIG. 52.



The relation between the thermoelectromotive force and the difference in temperature between the junctions may be expressed by an equation of the form

$$E = a\,t + b\,t^2 + c\,t^3$$

where one junction is kept at 0° C. and the other at t° C. For a large number of metals and alloys it has been found that only the second power of the temperature need be considered. The equation then becomes, to a very good approximation,

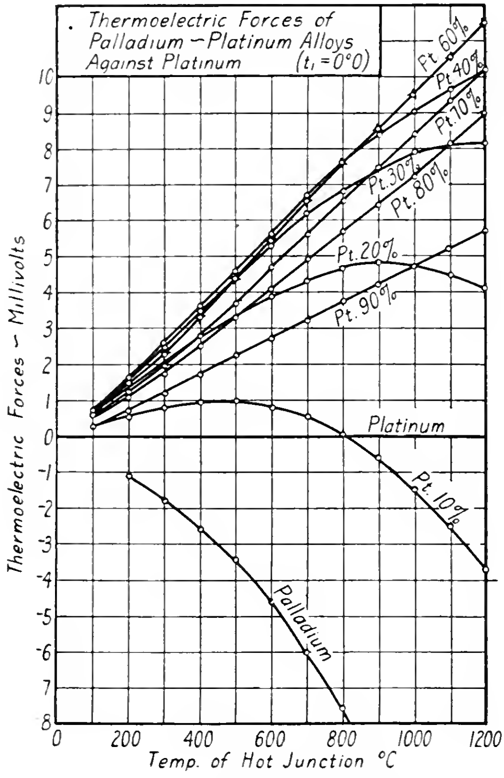
$$E = a\,t + b\,t^2.$$

In such a case the rate of variation of the thermoelectromotive force with the temperature becomes

$$\frac{d\,E}{d\,t} = P = a + 2\,b\,t.$$

This equation states that the thermoelectric power is a linear

FIG. 53.



function of the difference of temperature between the junctions. In some of the platinum-palladium alloys it has already been seen to be independent of the temperature. The rate of variation of the thermoelectric power with the temperature is

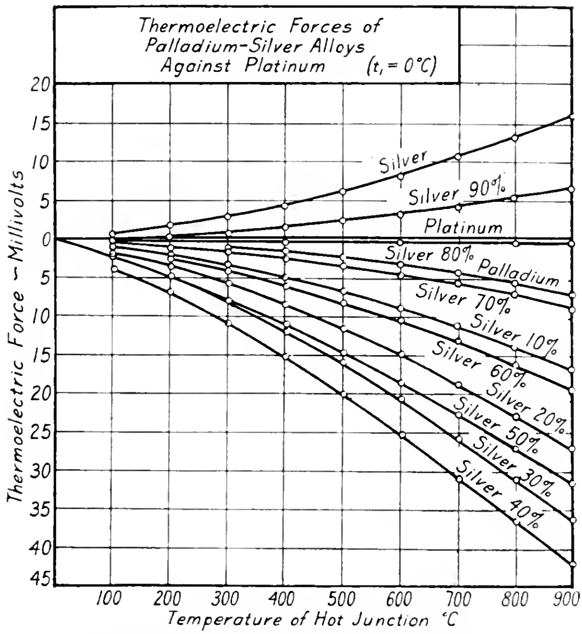
$$\frac{d\,P}{d\,t} = 2\,b.$$

In so far as the approximation introduced above is correct the variation of the thermoelectric power with the temperature is the same for all temperatures.

THEORIES OF RESISTANCE AND THERMOELECTROMOTIVE FORCES.

Lord Rayleigh[172] and Liebenow,[173] independent of each other, came to the conclusion that the increase in specific resistance which alloys show in excess of the resistance calculated from the resist-

FIG. 54.



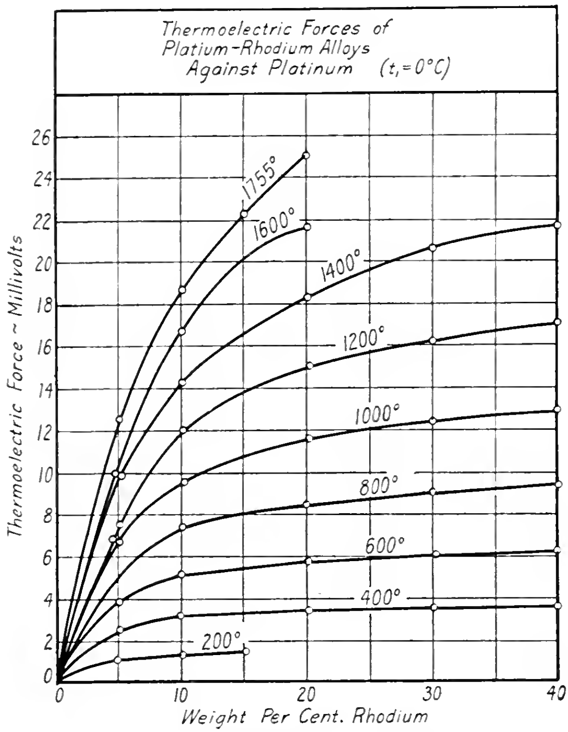
ance of their components may be attributed to the thermoelectromotive forces which arise between the junctions of the metals forming the alloys. According to these theories, the electrical current passing from one layer of metal to another layer of the other metal in the alloy develops or absorbs heat at the surface of contact between the components of the alloy, on account of the Peltier effect. These temperature differences cause thermoelectromotive forces to be set up in the alloy in such a way that they are equivalent to a large number of small cells connected in series, so that they oppose the flow of the current through the substance. They have, therefore, the effect of an added resistance. Since the difference in temperature between the contacts is proportional to the current flowing in the conductor, and since the thermoelectro-

[172] Lord Rayleigh: *Nature*, 54, 154, 1896.

[173] Liebenow: *Zeit. Electrochem.*, 4, 201 and 217.

motive forces are proportional to the difference in temperature, this back electromotive force is proportional to the current. The opposition to the flow of current through the alloy from this cause will, therefore, behave like a resistance and it will be impossible to distinguish between the ordinary resistance and that which arises from these thermoelectromotive forces. It is of importance

FIG. 55.

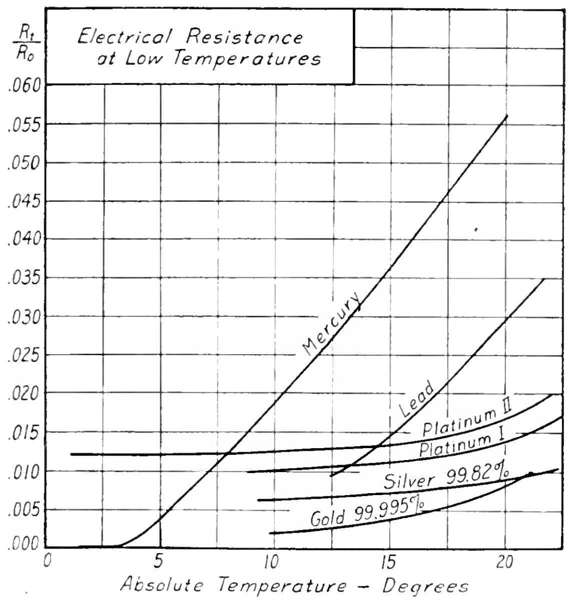


to note that where the constituents form compounds in which the resistance is high, it is necessary on the basis of this theory to assume a thermoelectromotive force between the molecules. Such an assumption is not very probable.

Some evidence for the correctness of this theory is found in the consideration of the way in which the electrical resistance of metals and alloys behaves at extremely low temperatures. When the temperature of a pure metal is decreased, the electrical resist-
temperature, until the temperature is 3 or 4 degrees above the
ance is found to be very accurately proportional to the absolute

absolute zero where the superconducting state appears and the electrical resistance almost entirely disappears. If, on the other hand, the temperature of an impure metal or alloy is decreased indefinitely, the resistance does not disappear at the absolute zero, but approaches a constant value. This suggests that there is in the resistance of an alloy an added constant term which does not disappear at the absolute zero. The theory of Lord Rayleigh leads at once to the existence of such a term. The added resistance arising from the causes considered in this theory does not seem large enough to account for the very high resistance of some alloys.

FIG. 56.



By reference to Fig. 56 it will be seen that the curve showing the relation between the electrical resistance of mercury and its temperature is nearly a straight line except near the origin. The curve for pure lead is also observed to be a straight line, but the corresponding curves for metals containing small admixtures of other metals do not seem to pass through the origin when prolonged backward. In such cases the electrical resistance seems to approach a constant value which persists to the absolute zero. Such a constant value is to be expected on the basis of the theory proposed by Lord Rayleigh and may, therefore, be taken as par-

tial evidence of the correctness of that theory. From the above point of view it is clear that it is impossible to prepare a good conductor by mixing two or more metals with each other. There will always be present this added resistance which makes the alloy at least not a better conductor than the constituents of which it is composed. Ordinarily the alloy is found to have a lower conductivity than would be calculated from its constituents by the additive law.

This theory of Lord Rayleigh may be stated more fully as follows:

Let R_o = the resistance of the alloy at 0° C.

γ = the temperature coefficient of resistance of the alloy.

R = the resistance of the alloy at 0° C. calculated from its constituents by the additive law.

α = the temperature coefficient of the alloy calculated by the additive law.

R_c = the contact resistance occurring at the surface of two metals forming the alloy.

β = the temperature coefficient of the constant resistance.

Then,

$$R_o\,(1+\gamma t) = R\,(1+\alpha t) + R_c\,(1+\beta t).$$

The resistance R_c is, according to Lord Rayleigh and Liebenow, caused by thermoelectromotive forces.

Where it is possible to assume that the temperature coefficients γ, α and β are independent of the temperature, it is possible to write,

$$R_o = R + R_c, \text{ and } 0^\circ \text{ C.},$$

and therefore,

$$R_o\,\gamma = R\,\alpha + R_c\,\beta,$$

at any temperature.

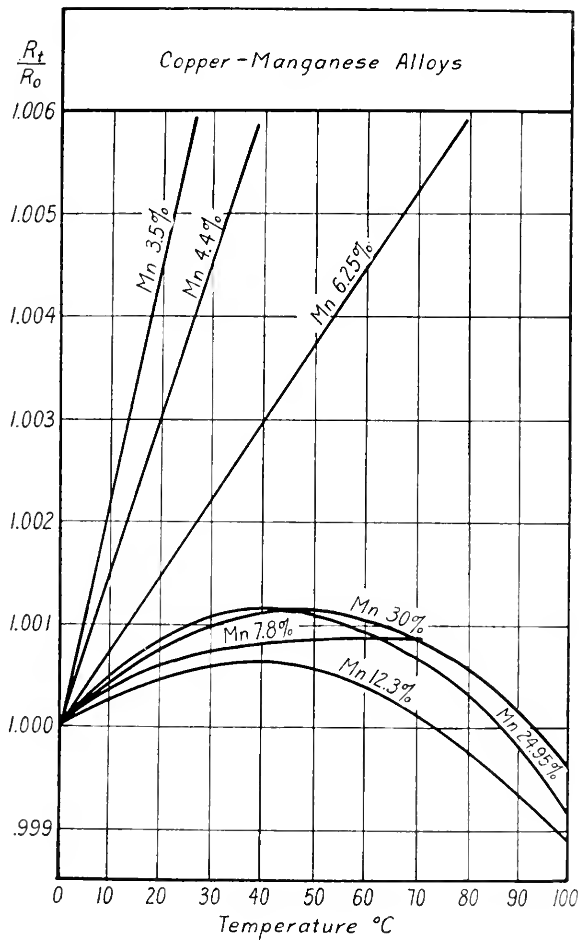
Whence,

$$\gamma = \frac{R\,\alpha + R_c\,\beta}{R_o}.$$

From this equation it is seen that γ may be negative when β is negative and $R_c\,\beta > R\alpha$. The temperature coefficient of alloys has been found negative in some cases. A well-known example is the case of copper-manganese alloys. Curves showing the ratio of the resistance at any temperature to the resistance at zero for some

copper-manganese alloys have been reproduced in Fig. 57. They are taken from the work of Guertler.[174] For an alloy containing 12.3 per cent. of manganese the temperature coefficient is positive above and negative below 40° C.

FIG. 57.



If it is possible to assume that $\beta = o$, that is, that the contact resistance is independent of the temperature,

$$R_o\ (l + \gamma\ t) = R\ (l + \alpha\ t) + R_c,$$

[174] Guertler: *Jahr. der Rad. und Elekt.*, 5, 17, 1908.

and since

$$R_o = R + R_c,$$

$$R_o \gamma = R \alpha$$

$$\frac{R_o}{R} = \frac{\alpha}{\gamma}.$$

This equation is equivalent to the empirical rule stated by Matthiessen and Vogt; namely, that the observed temperature coefficient of the resistance divided by that calculated from the additive law is equal to the observed electrical conductivity divided by the electrical conductivity calculated from the additive law. In so far as this rule may be accepted the curve for the electrical conductivity of a series of alloys ought to be the same as the curve for the temperature coefficient of that same series of alloys. In the preceding pages it has been seen that in very many cases there is a parallelism between the curve for the electrical conductivity and that for the temperature coefficient of the resistance. This parallelism offers satisfactory proof of the correctness of this rule in many cases.

The theory of Lord Rayleigh also leads to the second rule stated by Matthiessen and Vogt. Since

$$R_o(+l\gamma t) = R(l + \alpha t) + R_c,$$

and

$$R_o = R + R_c,$$

$$R_c = R_o - R =$$

difference between observed and calculated resistance at 0° C., and

$$R_c = R_o(l + \gamma t) - R(l + \alpha t) =$$

the difference between the observed and calculated resistance at t° C. Since each of these differences is equal to the contact resistance which has been assumed independent of the temperature, these differences ought to be the same for all temperatures. In other words, the difference between the observed and the calculated resistance is the same whatever the temperature. The large number of cases in which this rule has been found to be verified gives evidence that the temperature coefficient of the contact resistance is either zero or very small.

The increase in the electrical resistance of solid solutions over the resistance of the pure metals of which they are composed does

not find an easy explanation on the basis of the electron theory of metallic conduction. One assumption which has been made to explain this increase is that the number of free electrons in the alloy is much less than in pure metals. This assumption when considered in connection with Wiedemann and Franz's law does not lead to satisfactory results. The departures from this law, which states that the ratio of the thermal to the electrical conductivity is a constant for any particular temperature, are greater for alloys than for pure metals. These departures are always of such a nature that the electrical conductivity has been decreased more than the thermal conductivity by the formation of the alloy. This, with other considerations, has lead Schenck [175] to suggest that the increase in the electrical resistance of the alloy over the value calculated by the additive law could be accounted for by assuming that it arises from an increase in the frictional resistance which the electrons encounter in their motion through the alloy. This increase in frictional resistance to the motion of the electrons may be thought of as produced in a way very analogous to the way in which on the basis of the kinetic theory the addition of one gas to another causes an increase in the viscosity. Schenck thinks that the slowly diffusing molecules of the added metal hand on their energy and thus participate in the thermal conductivity but not in the process of electrical conduction. For this reason the ratio of the thermal to the electrical conductivity in mixed crystals is greater than for pure metals, and this quotient increases with increasing concentration of the added metal. The ratio of these conductivities in alloys as in pure metals is approximately proportional to the absolute temperature.

According to the electron theory, the different concentration of the electrons in the two metals is the source of a diffusion current which is the cause of the thermoelectromotive force which arises when the junctions of two metals or alloys are at different temperatures.

Let e = the thermoelectromotive force per degree difference in temperature.
R = the gas constant in ergs.
F = 965,450 coulombs.
N_a = number of electrons per cubic centimetre in A.
N_b = number of electrons per cubic centimetre in B.

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[175] Schenck: *Ann. d. Phys.*, **32**, 261, 1910.

Then,

$$e = \frac{R}{F} \mathrm{Log}_e \frac{N_a}{N_b}.$$

Many alloys give such large values of the thermoelectromotive force against one of the pure metals of which they are composed that in the application of the above equation it is necessary to assume very large changes in the number of free electrons to be produced by adding one metal to the other. In order to avoid these improbable assumptions Schenck has introduced the assumption already referred to—that it is the friction of the free electrons rather than their number that is changed by alloying one metal with another. By using this assumption that there is an increase in the frictional resistance of the electrons in the alloys over the resistance which they experience in pure metals, Schenck has been able to derive a relation between the thermal and electrical conductivity of the alloy, the thermal and electrical conductivity of the pure metallic solvent, and the thermoelectric power of the alloy against the pure solvent.

Let k = thermal conductivity of the pure solvent.

σ = electrical conductivity of the pure solvent.

k' = the thermal conductivity of the alloy.

σ' = the electrical conductivity of the alloy.

π = the thermo-electromotive force of the solid solution against the pure solvent for 1° C. temperature difference between the junctions.

R = the gas constant.

e = the specific electrical charge = 96,540 coulombs.

Then for dilute solutions Schenck shows that

$$\pi = \frac{R}{2e} \mathrm{Log}_e \left(\frac{k'}{\sigma'} \div \frac{k}{\sigma} \right).$$

Some observations have been made by Bernoulli [176] to test the validity of this equation. The following table shows the kind of agreement which exists between the observed and calculated values.

[176] Bernoulli: *Ann. d. Phys.*, 33, 690, 1910.

Solvent.	Element in solution.	π Observed.	π Calculated.
Silver	2.73 per cent. Th.	2.8	2.6
	4.76 per cent. Th.	10.3	8.4
	4.00 per cent. Sn.	7.6	8.9
Cadmium.........	5.14 per cent. Hg.	2.8	2.2
	10.0 per cent. Hg.	2.6	3.0
Copper...........	5.00 per cent. Sn.	3.4	3.6
	3.11 per cent. Zn.	2.9	3.6
	5.00 per cent. Zn.	1.4	6.6
	3.94 per cent. Ni.	13.3	3.9
	17.30 per cent. Ni.	27.3	11.2

From this table it is seen that for dilute solutions fair agreement exists between the observed and the calculated values. The more concentrated the solution the less satisfactory is the agreement.

RESISTANCE AND HARDNESS.

A theory of electrical conductivity proposed by March[177] offers a possible explanation of the relation between the elastic properties and the electrical conductivity of alloys. According to this theory, the number of free electrons in a metal or alloy, and therefore the electrical conductivity, is in part, at least, determined by the characteristic frequency of vibration of the atoms about their positions of equilibrium. Whatever changes this characteristic frequency would change at the same time the elastic properties and the thermal and electrical properties. On the basis of this theory the number of free electrons decrease with increasing frequency of the characteristic vibration of the atoms. Whatever, therefore, decreases the frequency of the characteristic vibrations of the atoms increases the electrical conductivity of the substance. Hence, at the absolute zero where the characteristic frequency of vibration of the atoms is very small or else disappears, the electrical conductivity will be very large. This is, of course, exactly what is observed in metals at very low temperatures where they pass into the superconducting state.

The formation of a solid solution produces a change in the elastic properties which causes the characteristic frequency of vibration of the atoms to increase. This arises out of the fact

[177] March: *Ann. d. Phys.*, **49**, 710, 1916.

that in an alloy in which the components *A* and *B* form mixed crystals, a molecule of *A* and a molecule of *B* act on each other with greater force than that with which a molecule of *A* acts on a molecule of *A* or a molecule of *B* on a molecule of *B*. There is on this account an increase in the cohesive forces and consequently an increase in the characteristic frequency of vibration of the atoms. With this increase in frequency is associated a decrease in the number of free electrons and a corresponding increase in the electrical resistance. From this point of view it is possible to see that where such elastic properties as hardness or tensile strength have maximum values, the electrical resistance will have a maximum value and the electrical conductivity a minimum value. Many illustrations of this have been seen in the preceding curves.

If the two components *A* and *B* of the alloy are insoluble in each other, the force which the molecule *A* exerts on another molecule *A* or the force which a molecule *B* exerts on another molecule *B* exceeds the force which a molecule *A* exerts on a molecule *B* or that which a molecule *B* exerts on a molecule *A*. Consequently each of these classes of molecules will form a group of crystals and the alloy will be a conglomerate formed of groups of crystals of the two constituents. In such an alloy the characteristics of each constituent are retained and the physical properties are additive. The components will, therefore, retain their characteristic vibrations and their elastic properties as well as the number of free electrons, and the electrical conductivity will change in conformity to the additive law. The hardness which increases with the frequency of the characteristic vibration of the atoms should in such cases be a linear function of the concentration of one of the constituents in the alloy. In such alloys the electrical conductivity will also be a linear function of the concentration of one of the constituents. Many cases of this kind have been noted in the preceding pages. This theory seems to offer a possible explanation of some of the interesting relations noted among the physical properties of alloys. Although the theory may not be satisfactory in many particulars, it is without doubt very suggestive.

Grateful acknowledgment is made to the Engineering Experiment Station of the Ohio State University for generous financial assistance in aid of this work.

PHYSICAL LABORATORY,
OHIO STATE UNIVERSITY.

INTERNAL COMBUSTION ENGINES IN MARINE SERVICE.*†

BY

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PART II.

NEW STANDARDS OF TURBINE STEAMER AND MOTORSHIP MACHINERY COMPARED.

THE conclusions so far established, while pretty clear as to the relative value of the present standards of single-screw geared turbine with steam auxiliaries, and twin-screw, direct-coupled Diesel engines and Diesel electric auxiliaries, will be changed by new plans for using turbines and oil engines now under experimental trial or in prospect. However clear a justification may be found for a construction program based on economic zones of present machinery standards, conclusions must be checked against other possibilities that are available before adoption as a guide. This requires a review of these proposals, and a selection of that one in each of the two classes that seems to be most prominently under consideration, for a new comparison of turbine and oil-engine power, representative of the immediate future.

Steam-turbine propulsion has been studied in every possible variation of main and auxiliary machinery, and in many cases trial installations have been made. Some of these plans are found to be non-competitive with reference to the rest and need not be considered. Those that seem to promise results that compete better with the motorship are the ones that *reduce fuel consumption*, even at increased first cost and machinery weight, thus adopting some of the motorship advantages.

Steam consumption of the main turbine can be reduced only by changing pressure and superheat, or by an increase of speed beyond what has so far been regarded as suitable for gear reduc-

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* Presented at the Stated Meeting of the Institute held Wednesday, April 20, 1921.

† Concluded from page 45, vol. 192, July, 1921.

tion. The best turbine speed set by the Berg standard is 4030 R.P.M. for 4000 horsepower, to give least possible fuel consumption. This speed is higher than has so far seemed good for gearing, but is well adapted to a turbogenerator unit, as the generating element of electric drive. With such a high-speed turbogenerator unit some small gain in steam consumption can be secured. Higher steam pressures than 200 lbs. are not practical without a change in boiler cost, weight or type, and must be set aside for the present, but with it superheat of 200° F. is feasible and will help, especially with the turbo-electric drive which eliminates the reversing turbine. No gain in vacuum over the 28.5″ standard seems practicable without proportionately greater expense.

There is a much greater possibility of savings in modifying the auxiliaries than by raising speed and superheat of the main turbine, because of the great inefficiency of direct acting steam auxiliaries that will take from 12 per cent. to 20 per cent. of the steam used by the main unit, depending on conditions. Prospects of reducing this are best, when all auxiliaries are electrified, as this permits the use of an economical, electric generating set. A small, steam-turbine generating set will operate motor-driven pumps, winches and steering gear more economically than is possible by individual steam cylinders, besides carrying lighting and exciter loads, but at a greater installation cost. Once the auxiliaries are electrified, any other auxiliary generating set can be used and the most economical from the fuel point of view is the Diesel engine-driven generator.

Adoption of the Diesel engine generating set for operating motor-driven auxiliaries will reduce the auxiliary fuel consumption to the least possible, and make it practically the same as for the motorship except as loads differ slightly for steam condenser pumps against jacket circulating pumps, for example. Similarly, the adoption of the high-speed turbogenerator as the main unit for electric-drive propulsion will reduce the fuel consumption of this main unit to a minimum, the generator motor losses being substantially equal to the gears of the geared turbine drive.

This combination gives the lowest possible fuel consumption for a turbine ship and is, therefore, adopted as a standard of reference for the future to be compared with the new standard of Diesel engine arrangement.

Such a steam-turbine, electric-drive ship with Diesel electric

auxiliaries will give a fuel consumption for all purposes at sea under normal working conditions of about .95 lb. of fuel oil per hour per S.H.P., which is somewhat less than 20 per cent. over the test value to allow for expected derangements of adjustments or condition of equipment. In port the fuel consumption will be substantially the same as for the Diesel ship, which is .6 ton per day, or 12 tons per port call of 20 days, equivalent to 79 barrels.

TABLE XIV.

Equipment List for Installation of Single-Screw Steam Turbine Electric Drive, 200 lbs. Steam Pressure, 200° Superheat, 28.5" Vacuum, 3500 S. H. P. at 90-100 R. P. M., Motor Aft., with Diesel Electric Auxiliaries.

Group	Equipment Item	Weight Tons	Cost Dollars
A	One 4100 H. P., 3500 S. H. P. turbogenerator set (A. C.) complete with controls	47.00	$50,000
B	Three Scotch boilers, full, complete with superheaters, stack, fuel oil, burner set, fuel and feed pumps and feed heater	320.00	80,000
C	Fresh water system, tank evaporator and distiller	6.00	1,500
D	Engine room power auxiliaries, condenser, pumps motor driven	23.00	23,000
E	Engine room ship auxiliaries, ballast, fire and bilge, sanitary, bilge and fresh water pumps, motor driven.	6.00	2,900
F	Three Diesel electric generating sets, 150 H. P. complete with air bottle, silencers and piping	66.00	48,000
G	One 50 H. P. oil engine emergency generating set with air compressor	6.00	6,000
H	Fixed engine and boiler room equipment, platforms, piping, full, tanks, spares, tools, stores	40.00	36,000
I	Deck auxiliaries, ten electric winches with windlass and steering gear	60.00	60,000
J	Power transmission—one 3500 H. P. motor complete with ventilation, mounting, shafts, bearings and propeller	85.00	63,000
	Total	659.00	$370,400
	Total per H. P.	.188 tons	$106.00

The electric-drive equipment of the turbine ship with Diesel electric auxiliaries will weigh more and cost more, than that of the gear drive with steam auxiliaries, and these items are to be balanced against the lower fuel consumption, which adds freight earnings, due to less fuel weight to be carried, and reduces expenses by the money value of the fuel saving.

The weights and costs of the various items of the equipment are collected in Table XIV, which, compared with Table I, shows

that the weight is 95 tons, or 2.7 per cent., heavier than the gear drive, and the cost $95,300, or 34 per cent., higher than the gear drive.

The calculations of cargo-capacity, yearly income from freight carried, disbursements and undistributed returns on capital investment, are taken up later, after the selection of a corresponding new type of Diesel ship with which this turbine electric drive is to be compared as to economic zones.

Modifications of Diesel oil engines, of propellor drives for oil engines, and of auxiliaries for such ships, over the previous standard of twin direct-coupled, four-cycle, air-injection, direct-reversing models with Diesel electric auxiliaries, are available in most bewildering variety. Some of these are just different, with no definite prospect of more economical cargo carrying than the present standard direct-coupled Diesel engine, nor any extension of its economical zone into that of the turbine ship. These novelties are natural in so young an art as that of oil engine construction, some of them may develop into something of real value, but for the present and for the immediate future, those modifications of existing standards that are worthy of immediate consideration are the ones that can meet the conditions as they are.

The conditions to be fulfilled are primarily—*reduction of cost and weight* of Diesel equipment, with the least possible sacrifice of fuel consumption and other existing features of merit that have been so far established. The prime consideration seems to be reduction of weight and cost of equipment, with space also important as bearing on bulk cargo-capacity.

Two general lines of effort here are recognized, each more or less independent of the other, though not completely.

1. Modification of propeller drive from the standard direct coupling of engine crankshaft to propeller;

2. Modifications of engine design from the standard air-injection, four-cycle, single-acting crosshead type.

With regard to the first: There are the two possibilities that have been applied to the turbine, the gear drive and the electric, and the adoption of which in the order stated, has converted the commercially unsuccessful direct-coupled steam turbine into the present success of the indirect, which permits complete independence of engine and propeller speeds. The weight of oil engines per horsepower decreases with decrease of cylinder size,

for the same mean piston speeds, even without any change in the design arrangements and proportions of the parts. The higher rotative speed of the smaller engines is not suitable for direct coupling of propellers, and an indirect connection is necessary before advantage can be taken of this sort of weight reduction. In fact, for such direct-coupled engines as are in successful service the low propeller speed has required long strokes, about 1.6 times the bore, which, with indirect coupling, may be made shorter or more nearly equal to the bore with corresponding advantage, by the increased rotative speed in weight reduction of the same horsepower capacity per cylinder. This situation is almost a direct parallel to that of the direct-coupled steam turbine and points directly toward a similar solution of gear drives or electric drives. Gear driving would be cheaper than electric drive for the same engine, and it permits the operation of a single screw which also saves weight over twin screws, with two engines driving one big gear. The reduction in engine weight for such a combination would not be great, however, not nearly so great as with a greater number of engines, which will permit very material increase of rotative speed, partly because of reduction of horsepower per cylinder but also by reason of shorter strokes. Such engine multiplicity becomes most practical with electric drive, in which case a single propeller shaft carrying a motor located aft, can be electrically connected to any number of high-speed, oil-engine generating sets, preferably D.C., and operating in series. The greater the number of these sets, the higher the speed and the lower the weight per horsepower.

The manœuvering advantage of this combination and its reliability factors, permitting one engine to be overhauled at sea with little loss of speed, have been much discussed and are now well understood. The objections against the plan lie in the very much larger number of cylinders, pistons, valves and other parts to be kept clean and in adjustment, and the fear that higher rotative speeds will mean lessened life. As to the latter point there seems to be no reason to fear lesser life with appropriate design and modern forced feed lubrication of all main running parts. Small parts of the valve gear and control system, subjected to inertia shocks, may so suffer, but these are all light, comparatively cheap, and with a multiplicity of engines can be cared for at sea in a way impossible with direct-coupled large units. There are hundreds of

such engines at work in stationary power plants, giving good service and proving their right to consideration for ship propulsion, exactly as happened with the steam turbogenerator sets now coming into use for steam-turbine electric drive. At sea no better proof of the reliability of high-speed engines can be found, than the performance of the German submarines in the late war, and which engines are now being manufactured by seven different firms in Germany for stationary power-plant service, in some cases superseding the designs developed by these firms, and that were formerly offered by them in competition.

All things considered, it seems proper to accept for the new model of Diesel ship to be compared with the turbine electric drive, the corresponding direct parallel which is the Diesel electric drive, with considerable multiplicity of generating units to get the weight reduction desired, and with electric auxiliaries, but without auxiliary generating sets except for a small engine to be used in port when not handling cargo.

There still remains the question of the engine itself. Here the variety of possibilities is almost infinite, but it is not necessary for the present to go into all of these in detail because we now have available suitable engines for the purpose and as new forms develop, for either direct-coupled service, gear-drive or electric-drive, the value of each will be determined by ordinary engineering analyses and commercial competition. Some of these suggestions are, however, worthy of mention, as bearing on the future possibility of further advances in the oil-engine art, a matter of particular interest in view of the fact that the steam turbine has very nearly reached its limit in the high-speed turbogenerator unit. Some of these items of possibility, development of which will be watched with interest, are:

1. Revival of the two-cycle competition with four-cycle;

2. Double-acting engines, especially two-cycle;

3. Special mechanism arrangements of which Junkers and Fullagar are examples;

4. Higher mean effective pressure rating of all engines over the present standard of 70 lbs. brake, by improved spraying and special combustion chamber arrangements to utilize more of the air charge than the present 50 per cent. approximately. In special cases over 100 lbs. mean-pressure brake have been reached;

5. Higher rating by supercharging with air, starting com-

pression with more than one atmosphere pressure, experimental values of 150 lbs. mean-pressure brake have been secured;

6. Improved construction of cylinder liners, heads and pistons to permit of higher rates of heat generation, and transmission to the jackets in B.T.U. per hour per sq. ft. without injury to the metal and possibly with special construction and special metals. The higher heat generating rates may be due to larger cylinders than now used, to higher speeds, or to increased amounts of oil per cu. ft. combustion chamber obtained by 4 or 5;

7. Elimination of compressed air as a spraying means by development of solid injection;

8. Reduction of metal weight per cu. ft. of cylinder by the more extensive use of steel instead of cast iron;

9. Development of new types of oil engine that do not fall under the Diesel classification, and might be called non-Diesel.

While all of these things are of great engineering interest, as showing further possibilities of development of good oil engines not yet realized, but which may well be expected to extend the commercial importance of the oil engine in the future over whatever proper economic position it has so far earned, it is not, as stated before, necessary to wait upon them, to make a material and useful change in the motorship now.

In considering this proposal for change, it must not be forgotten that the present standard direct-coupled, twin-screw Diesel ship discussed is a real success, and has a definite economic position in competition with the turbine that it will in all probability retain. The point in question is not the abandonment of this successful type of ship, but rather the development of another type of motorship that will have another and different economic position, also useful.

In selecting the Diesel electric drive with multiplicity of engines, as a model for comparison, it must be understood also that there is no implication of fixed superiority over other suggestions. This selection is made merely because it seems to be a promising and useful type with a field of its own, and the logical arrangement is to set up in comparison with the turbine electric drive with Diesel auxiliaries.

The Diesel electric motorship has some steam-turbine electric drive characteristics, the use of high-engine and low-propeller speeds in the interest of low cost and weight of machinery, and

with its advantages of control and manœuvering. To gain these things some fuel is sacrificed because it can be spared.

Similarly, the electric-drive turbine ship has borrowed from the motorship its identical economical auxiliary system to save fuel, but weight and cost are increased, again because there is plenty of margin.

The equipment items of the Diesel electric ship with the weights and estimated costs of each are collected in Table XV.

TABLE XV.

Equipment List for Installation of Single-Screw Diesel Electric Drive, 3500 S. H. P. at 90-100 R. P. M., Motor Aft., with Electric Auxiliaries.

Group	Equipment Item	Weight Tons	Cost Dollars
A	Seven 600-H. P. high-speed D. C. generating sets, 300 R. P. M. complete with exciters, controls, air bottles, valves, silencers	380.00	$ 90,000
B	One 50 K. W. auxiliary oil engine generating set with air compressor	11.00	9,000
C	One 50 K. W. oil engine generating separate exciter set complete	7.00	8,000
D	One donkey boiler, 200 sq. ft. with feed pump and oil burners for heating ship and fuel oil	8.00	1,000
E	Pumps for fresh water, ballast, fuel and lubricating oil, jacket circulating water, bilge, fire and bilge and sanitary uses motor driven, and steam emergency air compressor	20.00	15,000
F	Fixed equipment, additional piping stack and tanks, platforms	30.00	13,000
G	Deck auxiliaries, ten electric winches with windlass and steering gear	60.00	60,000
H	Power transmission, one –3500 H. P. electric motor complete with ventilators, mounting, shafts, bearings and propeller	110.00	95,000
	Total	626.00	$491,000
	Total per H. P.	.179 tons	$140.00

From this table it appears that the machinery weight of the Diesel electric drive is 626 tons, a reduction of 400 tons, or 40 per cent. of the weight for the direct-coupled Diesel, and the cost is $491,000 for the machinery, a reduction of 20 per cent., in spite of the addition of considerable electric equipment. This Diesel electric equipment of generators, motor and control weighs more and costs more than the corresponding turbine equipment because it is of the D.C. instead of A.C. type.

Independent of this electric equipment, the greatest single item of difference of the Diesel electric over the direct-coupled Diesel, is in the engines, which weigh only 150 lbs. per horsepower instead of 400 lbs. more or less. This is the direct result of high speed, 300 R.P.M. against 120 R.P.M., and a corresponding change from the crosshead to truck-piston type similar to the submarine and appropriate to such high-speed engines developing 100 horsepower per cylinder, instead of nearly 300 at the low speed. That such a change does not involve any hazard is proved not only by the success of such engines in stationary service, but also by comparison with the German submarine engine of 1200 horsepower in 6 cylinders at 450 R.P.M., brought to this country, tested and dismantled at the Philadelphia Navy Yard.

The engine is reported to have cylinders $18'' \times 16\frac{1}{2}''$ and gave good service at 450 R.P.M., at which figure the mean piston speed was 1240 feet per minute, a high value. The rated mean-pressure brake is 86 lbs. and the fuel consumption .42 lbs. per hour, per B.H.P. The engine weighs 57,000 lbs., or 47.5 lbs. per horsepower.

On the assumption that cargo service requires more conservative engine ratings, and lowest cost is not consistent with the least possible weight, the same engine might well be operated for commercial work at lower speed, lower rating, and be built with more metal to save shop expense. Reducing the rating mean pressure from 86 lbs. to the present standard of 70 lbs. and reducing speed from 450 R.P.M. to 300 R.P.M., and mean piston speed from over 1200 to about 800, the horsepower would be reduced from 1200 horsepower to 650 horsepower. With no change in metal weight, the engine would then weigh 88 lbs. per horsepower. It is, therefore, clear that the 150 lbs. per horsepower taken is very conservative, being nearly twice the weight of the submarine engine operated at reduced speed, and at standard commercial mean-pressure rating.

The two new electric-drive ships, steam turbine with Diesel electric auxiliaries, and the Diesel, can now be compared with each other as to economy of operation, by finding cargo capacities and yearly freight earnings, disbursements, and by their differences, the investment returns, using the same methods as were used for the present standard ships in Part I.

Cargo-capacities are determined from the dead-weight by subtracting the total of supplies of stores, water and fuel, which are based on the rates of consumption of the two ships per Table XVI.

TABLE XVI.

Consumption Rates of Consumable Supplies (Long Tons).

Item	Per Day At Sea		Per Day in Port	
	Steamship (Electric)	Motorship (Electric)	Steamship (Electric)	Motorship (Electric)
Stores	1.00	1.00	1.00	1.00
Water	13.00	3.00	3.00	3.00
Fuel	35.60	20.60	12 tons per call	12 tons per call

These rates are based on the assumption that stores and water consumption will be the same for the electric-drive ships as for the others, the only changes being in the fuel consumption, which for the turbine electric is lower than for the gear drive, and for the Diesel electric higher than for the Diesel direct-coupled.

TABLE XVII.

Consumable Supplies, Tons per Return Voyage.

Days, Single voyage		Stores		Water		Fuel		Total		Total Weight + Reserve	
Sea	Lay	Out	In	Out	In	Out	In	Out	In	Out	In
STEAMSHIP (ELECTRIC)											
5	20	50	25	125	125	178	178	353	328	388	361
10	20	60	30	190	190	356	356	606	576	·67	634
20	20	80	40	320	320	712	712	1112	1072	1223	1179
30	20	100	50	450	450	1068	1068	1618	1568	1780	1725
40	20	120	60	580	580	1424	1424	2124	2064	2336	2270
50	20	140	70	710	710	1780	1780	2630	2560	2893	2816
60	20	160	80	840	740	2136	2136	3136	3056	3450	3362
MOTORSHIP (ELECTRIC)											
5	20	50	25	75	75	103	103	228	203	251	223
10	20	60	30	90	90	206	206	356	326	392	359
20	20	80	40	120	120	412	412	612	572	673	629
30	20	100	50	150	150	618	618	868	818	955	900
40	20	120	60	180	180	824	824	1124	1064	1236	1170
50	20	140	70	210	210	1030	1030	1380	1310	1518	1441
60	20	160	80	240	240	1236	1236	1636	1556	1800	1712

From the consumption rates of Table XVI, the yearly totals of consumable supplies are determined for the same voyage lengths used before, and reported with 10 per cent. reserves in Table XVII.

The cargo-capacity in tons per voyage and in ton-miles per year are worked out and reported in Table XVIII and Table XIX, respectively, the last one giving also the yearly freight earnings. To show more clearly how these items compare for the two types

TABLE XVIII.

Dead-Weight Distribution (Long Tons).

(Average Single Voyage)

STEAMSHIP (ELECTRIC)

Sea Days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total Reserve	Cargo 10,000 − (Total + Reserve)
5	38	125	163	178	340	374	9626
10	45	190	235	356	591	650	9350
20	60	320	380	712	1092	1200	8800
30	75	450	525	1068	1593	1750	8250
40	90	580	670	1424	2094	2300	7700
50	105	710	815	1780	2595	2855	7145
60	120	840	960	2136	3096	3405	6595

MOTORSHIP (ELECTRIC)

Sea Days	Stores	Water	Stores Water	Fuel	Stores Water Fuel	Total Reserve	Cargo 10,000 − (Total + Reserve)
5	38	75	113	103	215	236	9764
10	45	90	135	206	341	375	9625
20	60	120	180	412	592	650	9350
30	75	150	225	618	843	927	9073
40	90	180	270	824	1094	1205	8795
50	105	210	315	1030	1345	1480	8520
60	120	240	360	1236	1596	1755	8245

of ships, the results are plotted in curve form in Figs. 11, 12 and 13, which are comparable with Figs. 1, 2 and 3 for the two ships without electric drives.

Disbursements for the electric-drive ship are very difficult to estimate not only for the reasons that apply to everything else, uncertain wages, rates and prices, but particularly because of lack of experience with these new ships the quantities involved are not established. About the only course open is to assume that such items as maintenance, crew wages and subsistence, loss and dam-

TABLE XIX.

Cargo (D. W.) Capacity and Yearly Gross Freight Earnings.

STEAMSHIP (ELECTRIC)

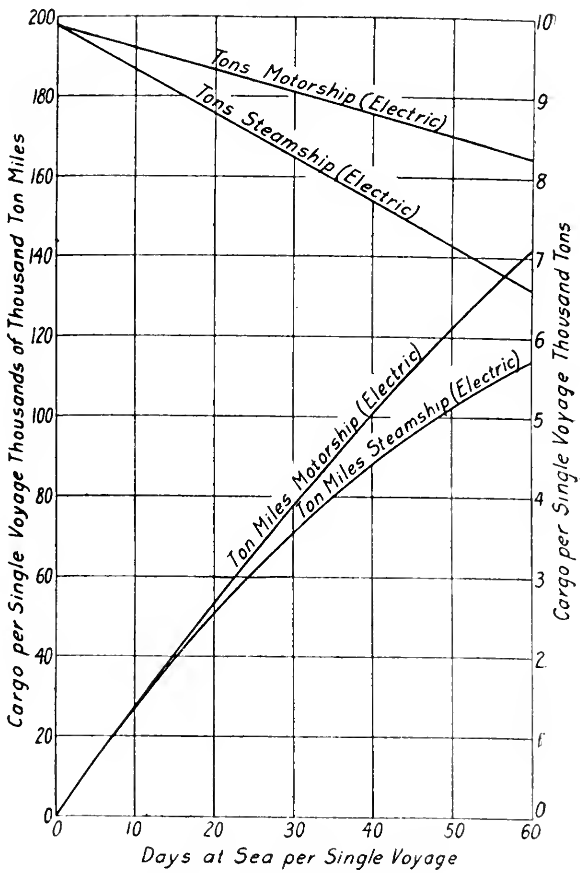
Days per single voyage		D.W. per single voyage		Distance, miles	Ton-miles cargo per single voyage	Single voyage per year 350 days	Thousand ton-miles per year	Gross earnings at freight rates per 1000 ton-miles of		
Sea	Lay	Supply	Cargo					$1.00	$2.00	$3.00
5	20	374	9626	1,440	13,850	14.00	194,000	194,000	388,000	582,000
10	20	650	9350	2,880	26,900	11.65	313,000	313,000	626,000	939,000
20	20	1200	8800	5,760	50,700	8.75	443,000	443,000	886,000	1,329 000
30	20	1750	8250	8,640	71,250	7.00	498,000	498,000	996,000	1,494,000
40	20	2300	7700	11,520	88,700	5.84	517,000	517,000	1,034,000	1,551,000
50	20	2855	7145	14,400	102,800	5.00	514,000	514,000	1,028,000	1,542,000
60	20	3405	6595	17,280	113,800	4.38	498,000	498,000	996,000	1,494,000

MOTORSHIP (ELECTRIC)

Sea	Lay	Supply	Cargo	Distance, miles	Ton-miles cargo per single voyage	Single voyage per year 350 days	Thousand ton-miles per year	$1.00	$2.00	$3.00
5	20	236	9764	1,440	14,050	14.00	197,000	197,000	394,000	591,000
10	20	375	9625	2,880	27,700	11.65	323,000	323,000	646,000	969,000
20	20	650	9350	5,760	53,800	8.75	471,000	471,000	942,000	1,413,000
30	20	927	9073	8,640	78,400	7.00	548,000	548,000	1,096,000	1,644,000
40	20	1205	8795	11,520	101,000	5.84	590,000	590,000	1,180,000	1,770,000
50	20	1480	8520	11,400	122,600	5.00	613,000	613,000	1,226,000	1,839,000
60	20	1755	8245	17,280	142,300	4.38	623,000	623,000	1,246,000	1,869,000

age, stores and port charges will be the same for the electric-drive as for the non-electric-drive ships of the two types, and then having determined the yearly returns, see if the differences are of such

FIG. 11.

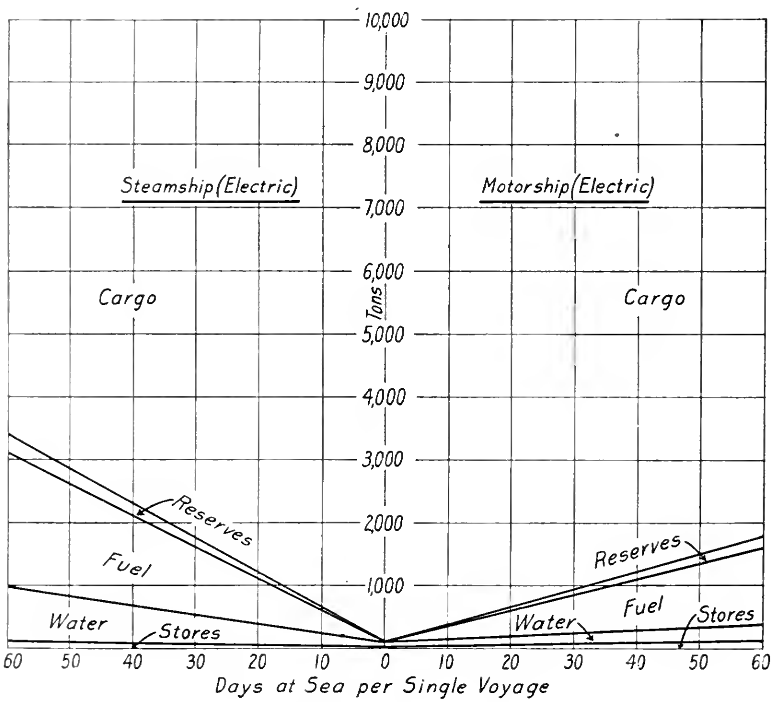


Cargo-Capacity per Single Voyage Tons and Ton-Miles.

an order of magnitude as might change conclusions should the items assumed equal, be not so within a possible range. This is equivalent to saying that if the yearly returns of the two types of ship are so close that the balance will be thrown one way or the other, solely on maintenance and crew expenses, they are really competitive and attention can then be concentrated on these items

As a matter of fact, it is found that the economic zoning of the operating field of the two types is so definite as to be not seriously disturbed by any reasonable changes here. It is likely that crew expense will be greater for both electric-drive ships, and that maintenance of the Diesel electric will be greater than for the direct-coupled Diesel, but the difference cannot be large in its effect

FIG. 12.



Dead-Weight Distribution in Tons.

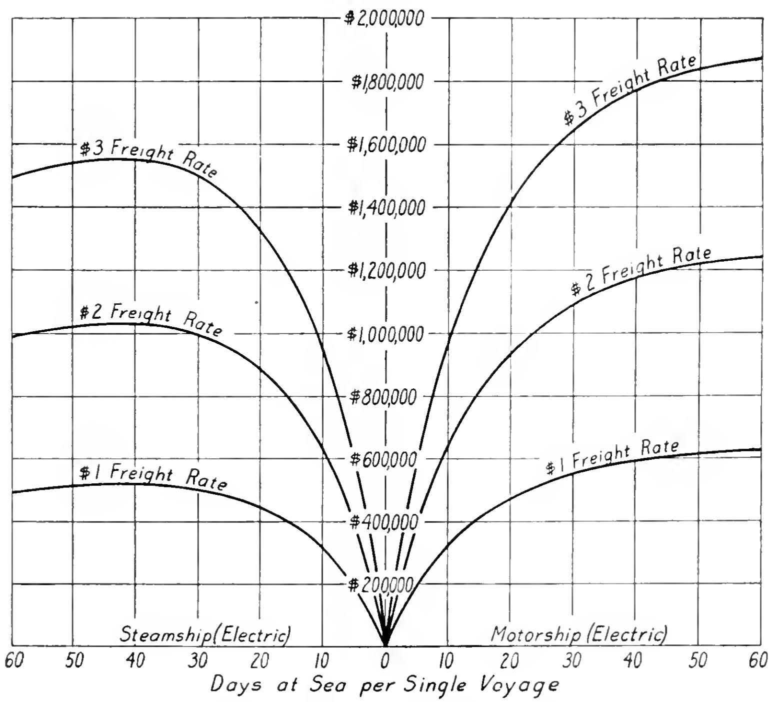
on yearly returns, and in any case is necessarily offset by greater reliability of drive and facility of manœuvering, which assurance against breakdown, collision or delay, may well be regarded as worth something.

Disbursements for insurance and fuel are different. That for insurance is in proportion to the new first costs, 5 per cent. on which produces the charge of $67,250 and $73,300 per year against the turbine and Diesel electrics, respectively.

These annual disbursements, exclusive of fuel, are collected in Table XX.

Disbursements for fuel are in proportion to consumption and to the price per barrel, and are collected in Table XXI for fuel prices from $1 to $5 per barrel.

FIG. 13.



Gross Freight Earnings per Year in Dollars.

Collecting all the disbursement items, the total annual expenses are given in Table XXII, and plotted in Fig. 14 for the electric-drive ships, which is comparable with Fig. 4 for the non-electric. It is clear from such a comparison that expenses for the Diesel electric are higher than for the direct-coupled, and for the turbine electric lower than for the geared turbine. The totals are closer together than before, as was also the case for freight earnings, and for first costs, too.

TABLE XX.

Fixed Annual Disbursements.

Item	Steamship (Electric)	Motorship (Electric)
Maintenance	$ 32,000	$ 32,000
Crew wages and subsistence	73,300	73,300
Loss and damage	3,650	3,650
Stores	21,900	21,900
Insurance	67,250	73,300
Total	$198,100	$204,150

YEARLY PORT CHARGES, BOTH SHIPS

Day per single voyage	Single voyages per year port calls	Yearly port charges approximate
5	14.00	$112,000
10	11.65	93,200
20	8.75	70,000
30	7.00	56,000
40	5.84	46,700
50	5.00	40,000
60	4.38	35,040

TABLE XXI.

Annual Fuel Expense.

STEAMSHIP (ELECTRIC)

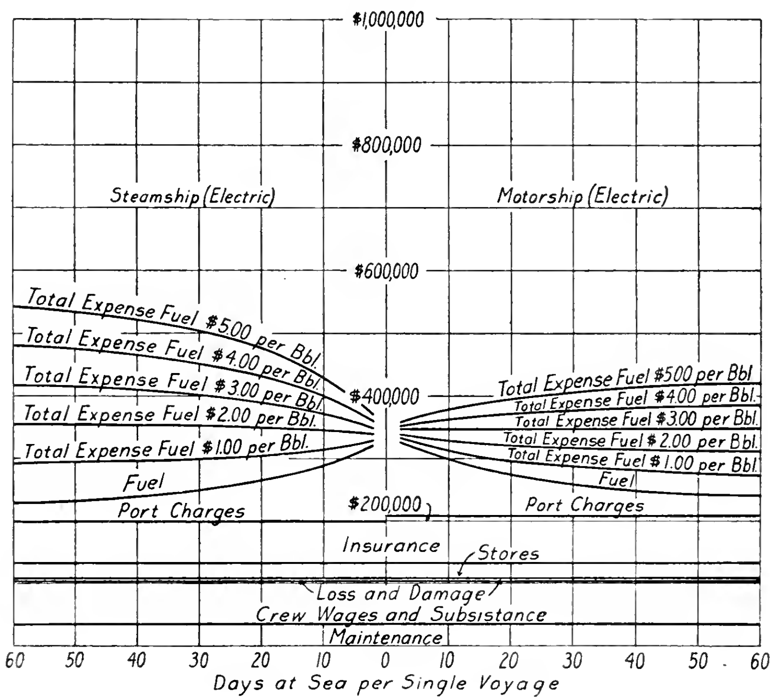
Days per single voyage	Single voyages per year	Fuel tons per single voyage	Fuel tons per year	Fuel bbls. per year	Fuel expense per year at dollars per bbl. of 1	2	3	4	5
5	14.00	178	2490	16,500	$16,500	$ 33,000	$ 49,500	$ 66,000	$ 82,500
10	11.65	356	4140	27,400	27,400	54,800	82,200	109,600	137,000
20	8.75	712	6225	41,200	41,200	82,400	123,600	164,800	206,000
30	7.00	1068	7480	49,500	49,500	99,000	148,500	198,000	247,500
40	5.84	1424	8320	55,100	55,100	110,200	165,300	220,400	275,500
50	5.00	1780	8900	58,900	58,900	117,800	176,700	235,600	294,500
60	4.38	2136	9350	61,900	61,900	123,800	185,700	247,600	309,500

MOTORSHIP (ELECTRIC)

Days per single voyage	Single voyages per year	Fuel tons per single voyage	Fuel tons per year	Fuel bbls. per year	1	2	3	4	5
5	14.00	103	1445	9,570	$ 9,570	$19,140	$ 28,710	$ 38,280	$ 47,850
10	11.65	206	2400	15,900	15,900	31,800	47,700	63,600	79,500
20	8.75	412	3610	23,900	23,900	47,800	71,700	95,600	119,500
30	7.00	618	4330	28,700	28,700	57,400	86,100	114,800	143,500
40	5.84	824	4810	31,900	31,900	63,800	95,700	127,600	159,500
50	5.00	1030	5150	34,100	34,100	68,200	102,300	136,400	170,500
60	4.38	1236	5420	35,900	35,900	71,800	107,790	143,600	179,500

Just how these three consistent related charges will affect the respective earnings of the two types of electric-drive ship is not clear without detailed figures on the per cent. returns for each combination of the three freight rates, \$1, \$2 and \$3 per 1000 ton-miles, with the five fuel oil prices of \$1, \$2, \$3, \$4 and \$5 per barrel.

FIG. 14.



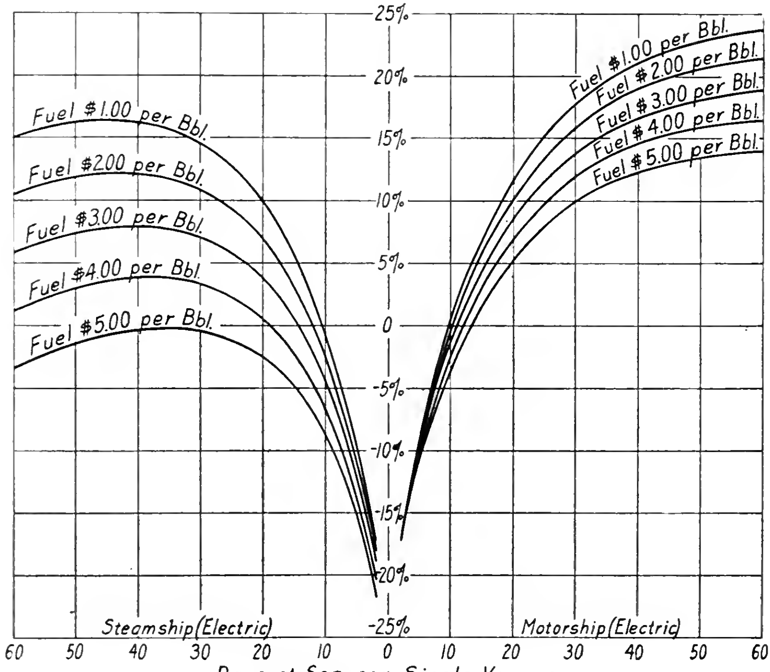
Total Annual Expense.

These per cent. returns are collected in Table XXIII (A, B, and C) for the three freight rates, respectively, and plotted in Figs. 15, 16, and 17. These curves of per cent. returns for the two electric-drive ships are directly comparable with the corresponding curves, Figs. 5, 6, and 7, for the non-electric, which are very similar in relation, and, of course, identical in form.

While these figures fix the relative economic positions of the two types of electric-drive ship, it is not easy to see at a glance

the effect of freight rates and fuel oil prices. To assist in this, the per cent. returns on the investment for every condition computed, are collected and arranged in Table XXIV, which is directly comparable with Table XIII for the non-electric ships. The per cent. returns on the investment represents the undistributed yearly excess of freight income (or deficit) over disbursements, divided

FIG. 15.



Annual Return on Investment with Freight Rate of $1.00 per 1000 Ton-Miles.

by the investment cost of the ship, from which profit and loss is to be determined after providing for book reserves.

To make clear just how the returns for one ship compare with another for any one condition, the curves are replotted with turbine and Diesel curves superimposed in Figs. 18, 19 and 20 for freight rates of $1, $2 and $3.

These figures show that long voyages, high fuel prices and low freight rates favor the motorship which always has a clear non-competitive field in the longer voyages, and when voyages are short, it is more or less equal to or competitive with the steamer per 1000 ton-miles, respectively.

TABLE XXII.

Total Annual Expense.

STEAMSHIP (ELECTRIC)

Days per single voyage	Total expense with fuel in dollars per bbl. at				
	$1.00	$2.00	$3.00	$4.00	$5.00
5	327,000	343,000	360,000	376,000	393,000
10	319,000	346,000	373,000	401,000	428,000
20	309,000	350,000	392,000	433,000	474,000
30	304,000	353,000	403,000	452,000	502,000
40	300,000	355,000	410,000	465,000	520,000
50	297,000	356,000	415,000	474,000	533,000
60	295,000	357,000	419,000	481,000	543,000

MOTORSHIP (ELECTRIC)

5	326,000	336,000	345,000	355,000	365,000
10	313,000	330,000	345,000	361,000	377,000
20	299,000	322,000	346,000	370,000	394,000
30	289,000	318,000	347,000	375,000	404,000
40	283,000	315,000	347,000	379,000	411,000
50	279,000	313,000	347,000	381,000	415,000
60	275,000	311,000	347,000	383,000	419,000

Where a curve of one ship crosses the corresponding curve for the other, the ships are equal in returns; on one side of the crossing one ship is superior and on the other side the other is more profitable. In this way the competitive and non-competitive zones are pretty clearly defined.

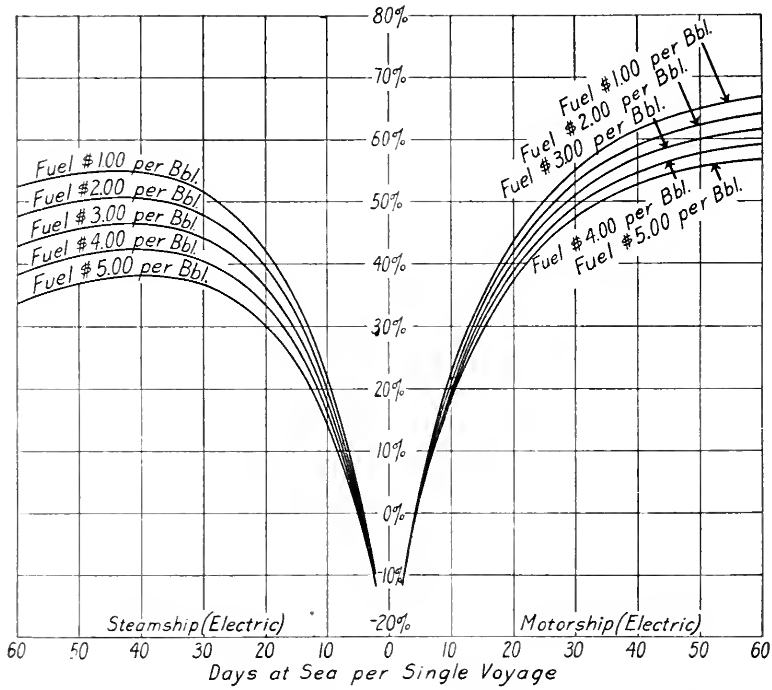
Inspection of these curves and the figures of the last table enable the following conclusions to be drawn with regard to these economic zones in terms of length of voyage, freight rate and fuel price.

Starting with a fuel price of $3 per bbl. and a freight rate of $1 per 1000 ton-miles, both ships show a loss for voyages of less than 10 days. The motorship consistently yields better returns for longer voyages: 8.5 per cent. *vs.* 3.7 per cent. for 20 days, 13.7 per cent. *vs.* 7 per cent. for 30 days, 16.6 per cent. *vs.* 8 per

cent. for 40 days, 18 per cent. *vs.* 17.4 per cent. for 50 days, 18.8 per cent. *vs.* 5.9 per cent. for 60 days.

For the $2 freight rate, neither ship shows a loss, but the Diesel is better over the whole range, the figures being, 3.3 per cent. *vs.* 2 per cent. for 5 days, 20.5 per cent. *vs.* 18.8 per cent. for 10 days, 40.4 per cent. *vs.* 36.7 per cent. for 20 days, 51 per cent.

FIG. 16.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

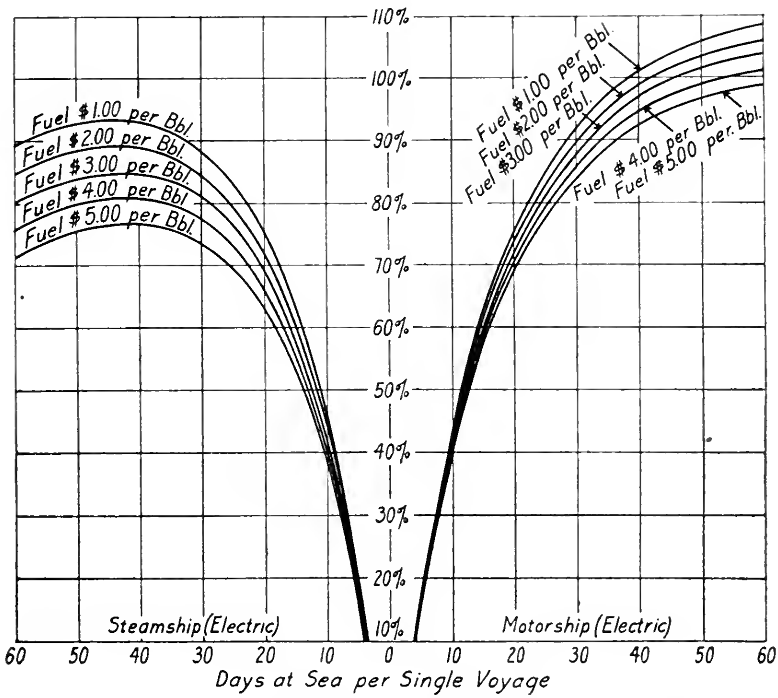
vs. 44 per cent. for 30 days, 56.8 per cent. *vs.* 46.3 per cent. for 40 days, 52.8 per cent. *vs.* 45.6 per cent. for 50 days, and 61.2 per cent. *vs.* 43 per cent. for 60 days, the difference increasing faster after 20 days.

For a $3 freight rate, the two ships are competitive on about an equal earning basis for voyages up to about 20 days, after which the motorship earnings increase faster, being 88.4 per cent. *vs.* 81.2 per cent. for 30 days, 97.2 per cent. *vs.* 85 per cent. for

40 days, 102 per cent. *vs.* 84 per cent. for 50 days, and 104 per cent. *vs.* 80 per cent. for 60 days.

At a higher fuel price of $4 per bbl., and with a $1 freight rate, both ships show a loss up to 10 days, after which the motorship is uniformly better. The figures are 6.9 per cent. *vs.* 0.7 per

FIG. 17.



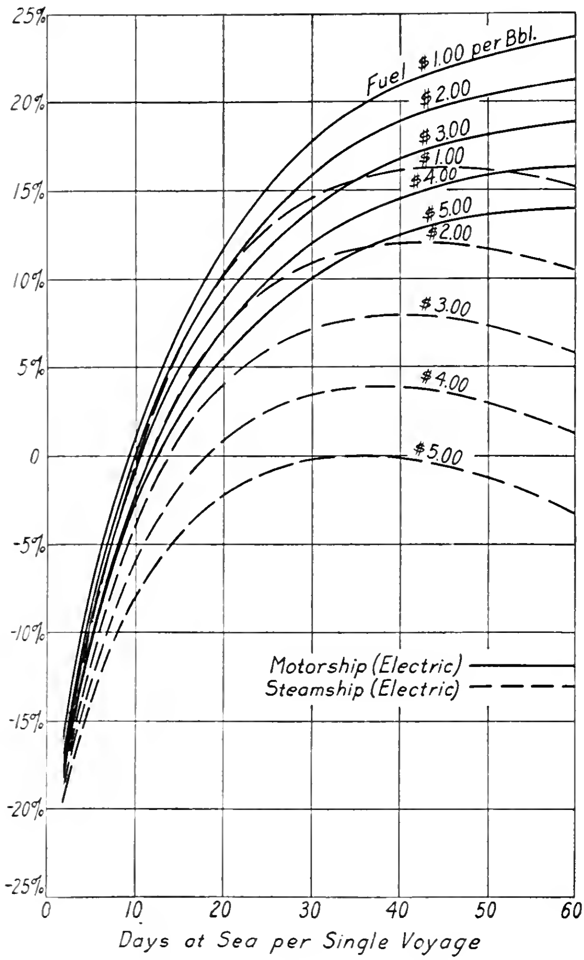
Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

cent. for 20 days, 11.8 per cent. *vs.* 3.4 per cent. for 30 days, 14.4 per cent. *vs.* 3.9 per cent. for 40 days, 15.8 per cent. *vs.* 3 per cent. for 50, and 16.4 per cent. *vs.* 1.3 per cent. for 60 days.

At a $2 freight rate, there is no loss, and both ships are about equal up to 20 days, the motorship gaining beyond this. The returns are 49.1 per cent. *vs.* 40.4 per cent. for 30 days, 54.3 per cent. *vs.* 42.3 per cent. for 40 days, 57.5 per cent. *vs.* 41.2 per cent. for 50 days, and 58.8 per cent. *vs.* 38.3 per cent. for 60 days.

For a \$3 freight rate, the ships are about equal for voyages for 10 days, after which the motorship *vs.* turbine figures are 71.3 per cent. *vs.* 66.6 per cent. for 20 days, 86.5 per cent. *vs.* 77.5 per

FIG. 18.



Annual Return on Investment with Freight Rate of \$1.00 per 1000 Ton-Miles.

cent. for 40 days, 95 per cent. *vs.* 80.8 per cent. for 40 days, 99.5 per cent. *vs.* 79.3 per cent. for 50 days, and 101 per cent. *vs.* 75 per cent. for 60 days.

TABLE XXIII (A).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rates of $1.00 Per 1000 Ton-Miles

Days per single voyage	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP (ELECTRIC) $1,345,000										
5	-133,000	- 9.90	-149,000	-11 08	-166,000	-12.33	-182,000	-13.52	-199,000	-14.80
10	- 60,000	- .55	- 33,000	- 2.53	- 60,000	- 4.46	- 88,000	- 6.55	-115,000	- 8.55
20	134,000	9.96	93,000	6.91	50,000	3.72	10,000	.74	- 31,000	- 2.30
30	194,000	14.42	145,000	10.78	95,000	7.06	46,000	3.42	- 4,000	- .30
40	217,000	16.13	162,000	12.04	107,000	7.96	52,000	3.87	- 3,000	- .22
50	217,000	16.13	158,000	11.75	99,000	7.35	40,000	2.98	- 19,000	- 1 41
60	203,000	15.10	141,000	10.50	79,000	5.87	17,000	1.26	- 45,000	- 3.35
MOTORSHIP (ELECTRIC) $1,466,000										
5	-129,000	- 8.80	-139,000	- 9.48	-148,000	-10.10	-158,000	-10.78	-168,000	-11.45
10	10,000	.68	- 7,000	- .48	- 22,000	- 1.50	- 38,000	- 2.59	- 54,000	- 3.68
20	172,000	11.72	149,000	10.17	125,000	8.53	101,000	6.89	77,000	5.25
30	259,000	17.66	230,000	15.69	201,000	13.70	173,000	11.80	144,000	9.83
40	307,000	20.92	275,000	18.75	243,000	16.57	211,000	14.39	179,000	12.21
50	334,000	22.79	300,000	20.45	266,000	18.13	232,000	15.82	198,000	13.50
60	348,000	23.71	312,000	21.27	276,000	18.80	240,000	16.37	204,000	13.91

TABLE XXIII (B).

Annual Return on Investment. Undistributed Excess or Deficit Freight Rate of $2.00 per 1000 Ton-Miles.

Days per single voyage	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP (ELECTRIC) $1,345,000										
5	61,000	4.53	45,000	3.34	28,000	2.08	12,000	.89	− 5,000	− .37
10	307,000	22.80	280,000	20.80	253,000	18.80	225,000	16.72	198,000	14.72
20	577,000	42.80	536,000	39.85	494,000	36.70	453,000	33.70	412,000	30.60
30	692,000	51.40	643,000	47.80	593,000	44.10	544,000	40.40	494,000	36.80
40	734,000	54.50	679,000	50.40	624,000	46.30	569,000	42.30	514,000	38.20
50	731,000	54.30	672,000	49.90	613,000	45.60	554,000	41.20	495,000	36.80
60	701,000	52.20	639,000	47.50	577,000	42.90	515,000	38.30	453,000	33.70
MOTORSHIP (ELECTRIC) $1,466,000										
5	68,000	4.64	58,000	3.95	49,000	3.34	39,000	2.66	29,000	1.98
10	333,000	22.70	316,000	21.30	301,000	20.50	285,000	19.40	269,000	18.30
20	643,000	43.80	620,000	42.00	596,000	40.40	572,000	39.00	548,000	37.30
30	807,000	55.00	778,000	53.00	749,000	51.00	721,000	49.10	692,000	47.20
40	897,000	61.10	865,000	58.70	833,000	56.75	801,000	54.30	769,000	52.30
50	947,000	64.50	913,000	62.00	879,000	59.80	845,000	57.50	811,000	55.30
60	971,000	66.20	935,000	63.70	899,000	61.20	863,000	58.80	827,000	56.40

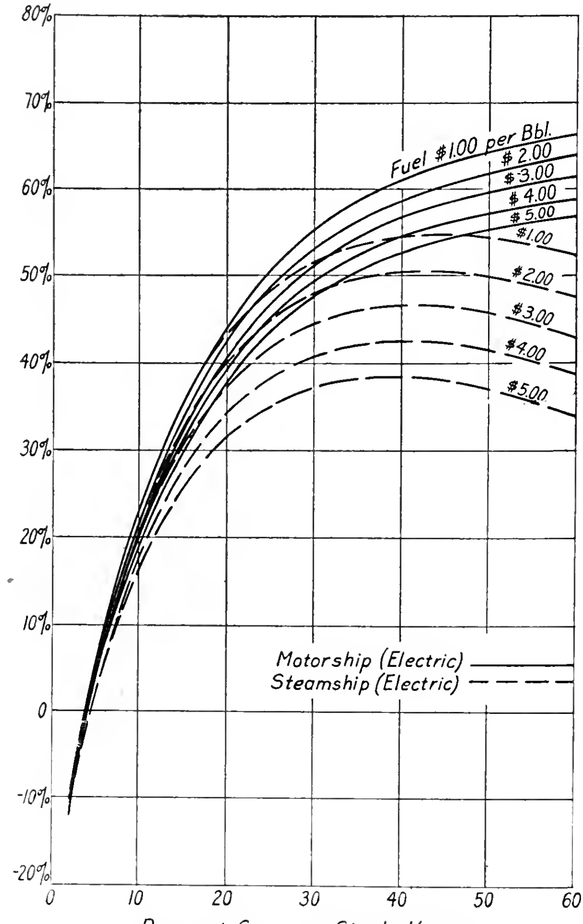
TABLE XXIII (C).

Annual Return on Investment. Undistributed Excess or Deficit. Freight Rate of $3.00 per 1000 Ton-miles.

Days per single voyage	Excess income over disbursements or deficit									
	Fuel at $1 per bbl.		Fuel at $2 per bbl.		Fuel at $3 per bbl.		Fuel at $4 per bbl.		Fuel at $5 per bbl.	
	Dollars	%	Dollars	%	Dollars	%	Dollars	%	Dollars	%
STEAMSHIP (ELECTRIC) $1,345,000										
5	255,000	18.95	239,000	17.76	222,000	16.50	206,000	15.31	189,000	14.05
10	620,000	46.10	593,000	44.05	566,000	42.10	538,000	40.00	511,000	38.00
20	1,020,000	75.90	979,000	72.70	937,000	69.60	896,000	66.60	855,000	63.60
30	1,190,000	88 50	1,141,000	84.90	1,091,000	81.20	1,042,000	77.50	992,000	73.70
40	1,251,000	93.00	1,196,000	88.90	1,141,000	84.90	1,086,000	80.80	1,031,000	76.70
50	1,245,000	92.60	1,188,000	88.30	1,127,000	83.80	1,068,000	79.30	1,009,000	75.00
60	1,199,000	89.10	1,137,000	84.50	1,075,000	79.90	1,013,000	75.40	951,000	70.70
MOTORSHIP (ELECTRIC) $1,466,000										
5	265,000	18.08	255,000	17.40	246,000	16.78	236,000	16.10	226,000	15.41
10	656,000	44.70	639,000	43.50	624,000	42.50	608,000	41.50	592,000	40.40
20	1,114,000	76.10	1,091,000	74.50	1,067,000	72.75	1,043,000	71.30	1,019,000	69.50
30	1,355,000	92.50	1,326,000	90.50	1,297,000	88.40	1,269,000	86.50	1,240,000	84.60
40	1,487,000	101.40	1,455,000	99.30	1,423,000	97 20	1,391,000	95.00	1,359,000	92.70
50	1,560,000	106.30	1,525,000	104.00	1,492,000	101.90	1,458,000	99.50	1,424,000	97.20
60	1,594,000	108.90	1,558,000	106.20	1,522,000	104.00	1,486,000	101.30	1,450,000	99.00

At the maximum fuel price of $5 per barrel, and with a $1 freight rate, the turbine ship shows a deficit over the whole range and the motorship for voyages under 20 days. Beyond this the

FIG. 19.



Annual Return on Investment with Freight Rate of $2.00 per 1000 Ton-Miles.

motorship returns are 9.8 per cent. for 30 days, 12.2 per cent. for 40 days, 13.5 per cent. for 50 days, and 13.9 per cent. for 60 days.

At $2 freight rate, the turbine ship loses under 5 days, but the motorship does not. The comparative figures for motorship *vs.* steamer are 18.3 per cent. *vs.* 14.7 per cent. for 10 days, 37.3 per cent. *vs.* 30.6 per cent. for 20 days, 47.2 per cent. *vs.* 36.8 per cent.

TABLE XXIV.

Per cent. Investment Return Compared

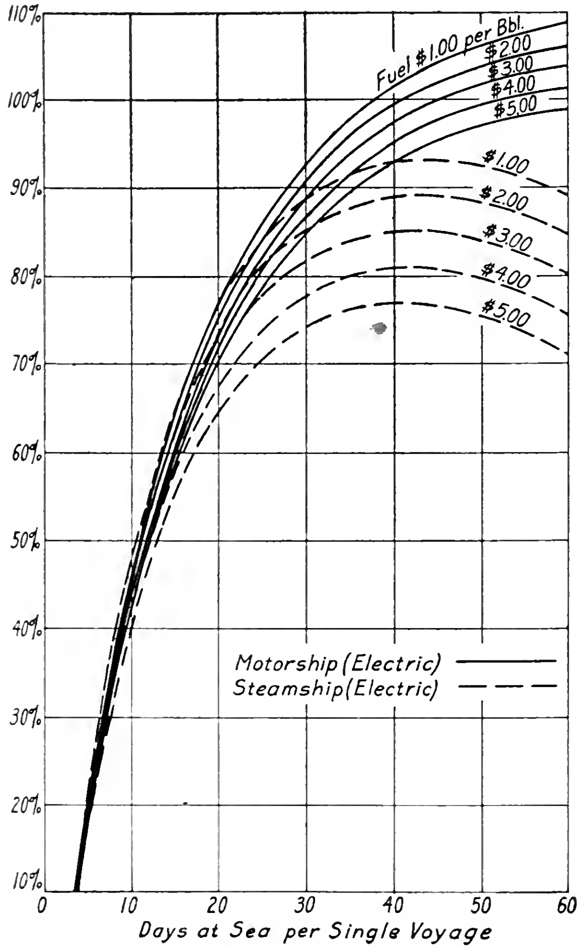
For

(a) Turbine (electric), single screw, Diesel auxiliaries
(b) Diesel (electric), single screw, Diesel auxiliaries

Days per single voyage	Freight dollars 1000 ton-miles	Fuel $1.00		Fuel $2.00		Fuel $3.00		Fuel $4.00		Fuel $5.00	
		Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel	Turbine	Diesel
5	$1.00	-9.90	-8.80	-11.08	-9.48	-12.33	-10.10	-13.52	-10.78	-14.80	-11.45
	2.00	4.53	4.64	3.34	3.95	2.08	3.34	.89	2.66	- .37	1.98
	3.00	18.95	18.08	17.76	17.40	16.50	16.78	15.31	16.10	14.05	15.41
10	1.00	- .55	.68	-2.53	- .48	-4.46	-1.50	-6.55	-2.59	-8.55	-3.68
	2.00	22.80	22.70	20.80	21.30	18.80	20.50	16.72	19.40	14.72	18.30
	3.00	46.10	44.70	44.05	43.50	42.10	42.50	40.00	41.50	38.00	40.40
20	1.00	9.96	11.72	6.91	10.17	3.72	8.53	.74	6.89	-2.30	-5.25
	2.00	48.90	48.80	39.85	42.00	36.70	40.40	37.70	39.00	30.60	37.30
	3.00	75.90	76.10	72.70	74.50	69.60	72.75	66.60	71.30	63.60	69.50
30	1.00	14.42	17.66	10.78	15.69	7.06	13.70	3.42	11.80	-.30	9.83
	2.00	51.40	55.00	47.80	53.00	44.10	51.00	40.40	49.10	36.80	47.20
	3.00	88.50	92.50	84.90	90.50	81.20	88.40	77.50	86.50	73.70	84.60
40	1.00	16.13	20.92	12.04	18.75	7.96	16.57	3.87	14.39	-.22	12.21
	2.00	54.50	61.10	50.40	58.70	46.30	56.75	42.30	54.30	38.20	52.30
	3.00	93.00	101.40	88.90	99.30	84.90	97.20	80.80	95.00	76.70	92.70
50	1.00	16.13	22.79	11.75	20.45	7.35	18.13	2.98	15.82	-1.40	13.50
	2.00	54.30	64.50	49.90	62.00	45.60	59.80	41.20	57.50	36.80	55.30
	3.00	92.60	106.30	88.30	104.00	83.80	101.90	79.30	99.50	75.00	97.20
60	1.00	15.10	23.71	10.50	21.27	5.87	18.82	1.26	16.37	-3.35	13.91
	2.00	52.20	66.20	47.50	63.70	42.90	61.20	38.30	58.80	33.70	56.40
	3.00	89.10	108.90	84.50	106.20	79.90	104.00	75.40	101.30	70.70	99.00

for 30 days, 52.3 per cent. *vs.* 38.2 per cent. for 40 days, 55.3 per cent. *vs.* 36.8 per cent. for 50 days, and 56.4 per cent. *vs.* 33.7 per cent. for 60 days.

FIG. 20.



Annual Return on Investment with Freight Rate of $3.00 per 1000 Ton-Miles.

At the maximum freight rate of $3 the motorship leads a little at first and then regularly by larger margins for longer voyages. The figures are 15.4 per cent. *vs.* 14 per cent. for 5 days, 40.4 per cent. *vs.* 38 per cent. for 10 days, 69.5 per cent. *vs.* 63.6 per cent. for 20 days, 84.6 per cent. *vs.* 73.7 per cent. for 30 days, 92.7 per cent. *vs.* 76.7 per cent. for 40 days, 97.2 per cent. *vs.* 75 per cent. for 50 days, and 99 per cent. *vs.* 70.7 per cent. for 60 days.

Comparing the electric-drive ships with the non-electric, it is evident that the electrification of both ships favors the motorship more than it does the turbine steamer, and reduces the voyage length at which the motorship emerges from the competitive field into its zone of no competition.

TABLE XXV.

Relation of Other Ships to the Geared Turbine Equipment with Steam Auxiliaries.

Item	Geared Turbine Steam Auxiliaries	Twin Diesel Direct Diesel Electric Auxiliaries	Electric Drive	
			Turbine Diesel Elec. Auxil.	Diesel
Weight of machinery	1.00	1.615	1.043	.99
Cost of machinery	1.00	2.11	1.348	1.785
Cost of ship	1.00	1.245	1.075	1.175
Cargo-capacity for 5 day voyage	1.00	.99	1.015	1.03
Cargo-capacity for 60 day voyage	1.00	1.358	1.11	1.39
Fuel consumption per day at sea	1.00	.395	.81	.468
Total yearly expense with fuel $1.00 per barrel and 5 day voyage	1.00	.987	.987	.976
Total yearly expense with fuel $1.00 per barrel and 60 day voyage	1.00	.894	.961	.896
Total yearly expense with fuel $5.00 per barrel and 5 day voyage	1.00	.815	.875	.813
Total yearly expense with fuel $5.00 per barrel and 60 day voyage	1.00	.635	.871	.672

At this point it is worth while to summarize the relation between the various items of equipment, cargo-capacity and disbursements for each of the four types of ships studied, and which are primarily responsible for the conclusions drawn as to economic zoning. For this purpose the figures for the geared turbine ship with steam auxiliaries are taken as unity, so all other figures represent a ratio of the figure for the other ship to that for the geared turbine. These ratios are collected in Table XXV.

Finally, it must be noted that while the conclusions drawn are pretty clear for the large freight vessel of 10,000 D.W.T., and limit the competitive turbine ship to the short-voyage zone, shorter for electric than for non-electric, with a clear field of superiority for long voyages, this short-voyage, competitive zone might well be better served by smaller ships. The smaller vessel of half the dead-weight capacity need remain in port for only half the time so far as cargo handling is concerned and, therefore, neglecting useless waiting time, it has the same ratio of sea time per year as the larger ship, when its voyages are half as long.

As smaller ships are better adapted for short voyages, it seems clear that the short-voyage condition for the larger ship should hardly be considered seriously except to bring out its limitations, and the better adaptability of the smaller ship.

Smaller ships require smaller horsepower and as horsepower per installation is lessened, the steam equipment becomes less adaptable than the oil engine in proportion, both in the direct-coupled units and with the electric drive. As size is reduced, the Diesel electric drive permits the use of the identical engine used for the larger ships but in lesser numbers and adoption of such engines would permit the use of manufacturing methods in their production, not possible when a large number of sizes of big low-speed engines are demanded for direct propulsion, a condition nearly identical with that of the German submarine engine though for different primary reasons. In this reduction of size of installation with identical engines of lesser number, a point will be reached where there are only two, or perhaps one, again bringing forward the geared or direct-coupled possibility, on the one hand, or a smaller engine of still higher speed and lesser weight to be used in larger multiples, on the other hand.

In conclusion, it can be said that the Diesel engine has a definite and useful zone of operation at sea with both the large direct-coupled forms now in use, but also with smaller sizes of higher speed used in multiple with universal application to a wide range of ship sizes and speeds by indirect drive. The former will undoubtedly remain in use, as there is no good reason in sight for retiring it, and if fuel prices rise, as would be natural, and freight rates fall, its position is further strengthened for long-voyage service. The high-speed engine used in multiples seems equally justified, and may well be adopted for immediate use in vessels intended for shorter voyages, vessels of both large and small size, and both for conversion of existing obsolete steamers, as well as for new construction. The use of Diesel machinery must, on economic grounds, definitely increase, and from this conclusion there is no alternative, but a proportionate decrease in steam-turbine machinery for cargo ships. The only clear non-competitive fields that the steam-turbine ship can claim for its own are, first, that in which coal is burned, and second, that of the very large or fast ships requiring more power than can be obtained by oil engines, and especially when speed is worth anything it might cost.

THE BIFILAR WINDBALANCE.*

By A. F. Zahm, Ph.D.

Bureau of Construction and Repair U.S.N.

Preface.—For the delicate measurement of air resistance along stream, in a wind tunnel, the model under test may be suspended from one or more wires, and either prevented by a dynamometer from drifting down stream, or allowed to drift without rotation—catapultwise—till the obliquity of the suspension prevents further displacement. Both methods have been used in various laboratories for more than a decade.

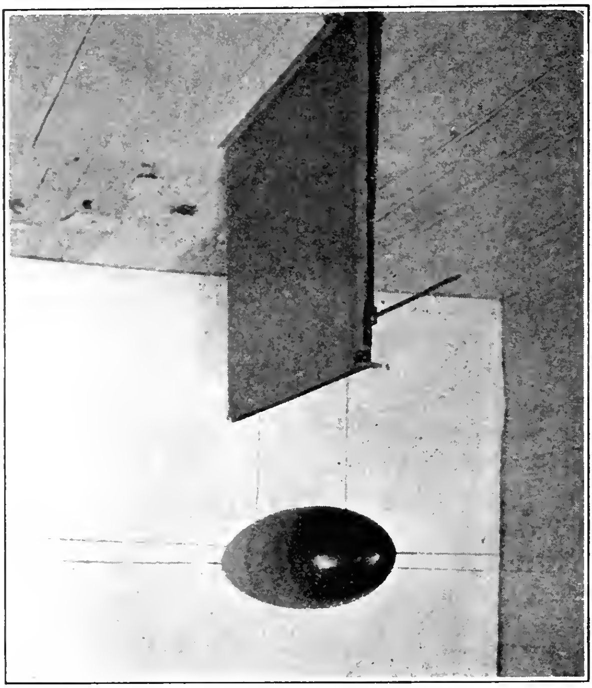
An example of the first method is found in the measurements of balloon resistance, first by Professor Prandtl of Göttingen University, and later by the National Physical Laboratory of England. Prandtl, in 1909, suspended Parseval hull models from the ceiling of his tunnel by four fine wires; two attached to the bow and sloping upward right and left; two similarly arranged at the stern. A mooring wire, running from the nose of the hull to a bell-crank balance arm, served to measure the resistance. In the British arrangement the bow was supported from the tunnel ceiling by a single wire, the stern was held by a tail pin whose pointed outer end rested in a hole in the spindle of an aerodynamic balance. Both apparatus proved satisfactory in use.

In 1902, the writer used the second or catapult method for the study of friction planes and aerofoils. Long skin-friction planes were supported at the centre of a wind tunnel by two fine steel wires running vertically through the tunnel ceiling, and attached to the top of the laboratory. Prow and stern pins gliding between stops steadied the planes laterally. The displacement of one suspension wire, carrying a sharp pointer along a fine steel scale lying on top of the tunnel, served to indicate the resistance of the friction board. Sometimes also four vertical wires, running from the corners of a large aerofoil up to a tiltable suspension frame, served to set the model at any incidence and to measure simultaneously its lift, drag and pitching moment. The tiltable frame feature was added in 1902 by Mr. H. Mattullath.

* Communicated by the Author.

Description of Bifilar Balance.—A bifilar balance, designed by the writer, is used at the Washington Navy Yard to measure the resistance of balloon hulls, struts, etc. Figs. 1 and 2 show the form of swing used for the study of hulls. Two steel wires, .02 inch in diameter, attached to the laboratory ceiling, run down through fine movable slots and a wind shield in the tunnel ceiling, and support the model near the middle of the air stream. At each

FIG. 1.



Airship hull suspended on bifilar windbalance.

end a 1/8 inch steel pin, gliding freely through an eyelet in a very fine stay wire stretched across the tunnel, steadies the model laterally.

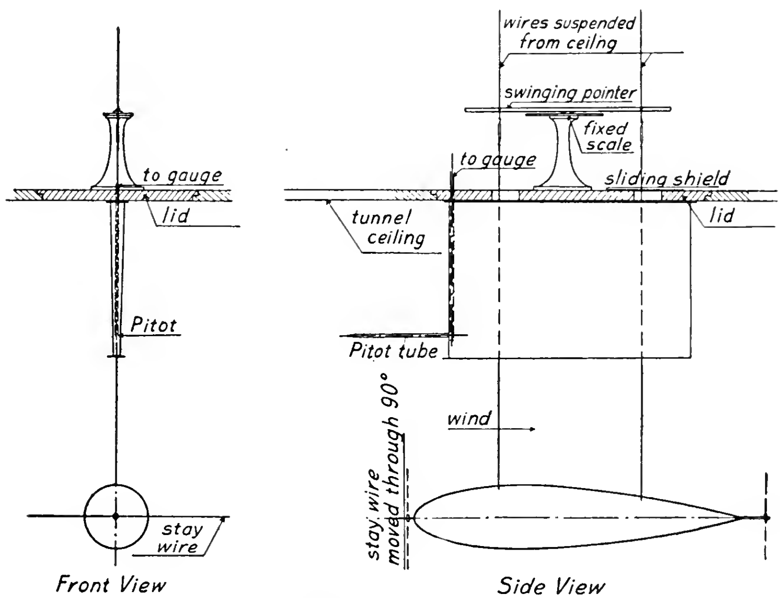
Above the tunnel a pointer fixed to a cross-bar joining the two suspension wires moves along a steel scale and when read with a lens indicates the deflection to a fraction of one-hundredth of an inch. The scale reading multiplied by the suspended weight,

divided by the length of wire above the scale, equals the deflecting force.

Very uniform and consistent readings are thus obtained. The air speed measured by the pitot-static tube fixed before the wind shield bears a known and fixed relation to the speed in the region where the model is to be inserted.

A well-shaped balloon hull can be placed about one diameter

FIG. 2.



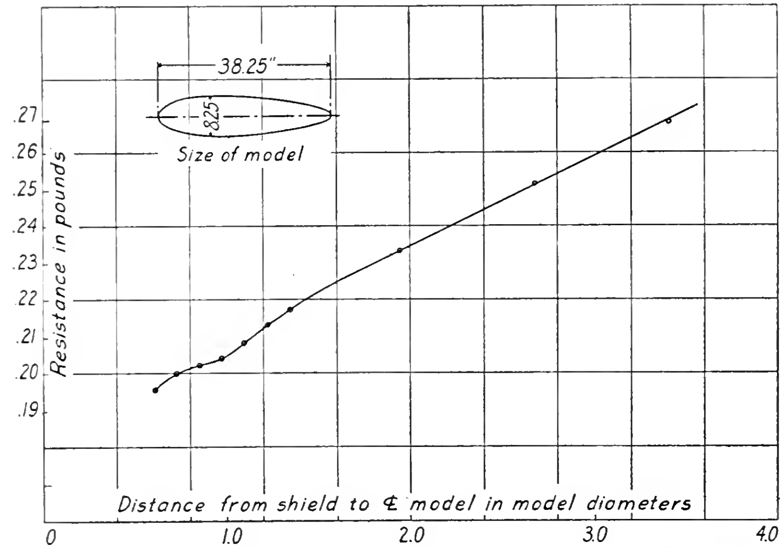
Bifilar windbalance.

from a suitable wind shield without blanketing or interference. This conclusion follows from observations of the air resistance of such a hull when held close to the shield, then successively further below it. The actual values of the resistance of a Parseval model in such a test are given in Fig. 3, together with the dimensions of the model and shield. Beyond two diameters, or somewhat nearer, the resistance of the model and its sustaining wires is directly proportional to its distance from the shield, that is proportional to the length of wire exposed. It is assumed that blanketing will be obviated by placing the model farther from the

wind shield than the distance represented by the curved part of the diagram in Fig. 3.

In another form of the bifilar balance the steel suspension wires support a heavy horizontal iron bar just within the bottom of the wind shield. From this bar light models may be suspended by fine wires running down into the wind. The bar is prevented from rolling by vertical lugs at its end, to which lugs the suspension wires are attached. It is steadied laterally by prow and stern pins running through holes in the wind shield. The front pin may

FIG. 3.



Resistance in terms of distance from wind shield. Wind speed 50 M. P. H.

serve as a holding stem for certain wind models, such as spheres, discs, cylinders, struts, etc. The horizontal bar can be loaded to any desired weight, to balance the air drag, by adding supplementary bars.

All forms of the balance require small corrections in the readings to allow for the resistance of the suspension wires and the disturbance of the air flow caused by them about the model. The method of making these corrections need not be detailed here.

Practical Usefulness.—In practical operation the swing balance has always proved satisfactory. It causes a minimum dis-

turbance of airflow about the model; it measures accurately; it is too simple to be erratic or uncertain in action. The resistance values obtained with it on models in a uniform wind, at ordinary flying speeds, usually plot on logarithmic paper as quite rectilinear, showing uniform consistency in the readings.

Origin.—In June, 1902, the writer described to the American Association for the Advancement of Science a swing balance, of two or more wires, as part of the equipment he had devised for the aerodynamic laboratory erected in 1901 in his department at the Catholic University of America; and in the *Philosophical Magazine* for July, 1904, he gave a sketch of the instrument as employed in measuring atmospheric friction on plane surfaces. The 1902 description follows:

"Another device that may prove valuable is known as the 'swing.' This consists of two or more fine steel wires fastened near the laboratory ceiling, and suspending wind objects inside the tunnel. The air resistance causes these objects to move down stream, and the consequent displacement of the wires, along their slots in the tunnel ceiling, is measured by a fixed meter-stick. The manner of using this instrument need not be given in detail, for its mechanical theory is very simple. An interesting feature of it is that, when the wind thrust is parallel to the tunnel, its magnitude is directly proportional to the deflection along the meter-stick.

"One valuable purpose of the 'swing' is to support long skin-friction boards or planes, within the tunnel, and indicate the amount of the skin resistance. Another important function is the support of very large aeroplanes at low angles of wind impact —planes which would not keep their shape if held in the usual way."

It may be added that the two front suspension wires ran up to prongs on one weighing axle, the two rear wires to prongs on another axle, both planted on a tilting frame which served to adjust and measure the incidence. The two weighings thus determined the lift and pitching moment. The drag could be computed from the down-stream displacement or measured by a nose wire attached to a weighing beam. This tilting-frame wire balance and the simple bifilar balance anticipated by many years the similar balances used in the aerodynamical laboratories of Europe.

Effect of Finely Divided Material on the Freezing Point of a Liquid.—F. W. Parker of the University of Wisconsin has studied this problem. (*Jour. Am. Chem. Soc.*, 1921, xliii, 1011–1018.) The finely divided, insoluble substances included ferric hydroxide, aluminum oxide, silica, and a silt loam; the liquids were water, benzene, and nitrobenzene. Determination was made of the freezing point of the mixture obtained by moistening a finely divided substance with one of the liquids. From a series of such determinations it was found that finely divided material produces a depression of the freezing point of a liquid, when that liquid is present as a film or in the capillary condition in the solid material. Moreover, the freezing point depression due to solid material and that due to material in solution are additive. Therefore the concentration of the soil solution cannot be determined by the freezing point method unless the moisture content be very high.

J. S. H.

The Glarimeter, an Instrument for Measuring the Gloss on Paper. L. R. INGERSOLL. (*Jour. Optical Soc. Am.*)—When light falls on a piece of paper, part of it is diffusely reflected and part is reflected specularly—that is, as from a mirror. This latter part is found by experiment to be almost completely plane polarized, when its angle of incidence on the paper is about 57.5 degrees. An eye-piece is set so as to receive the specularly reflected beam which has mingled with its also diffused light. Gloss is defined as the fraction of the brightness of the composite ray due to the plane polarized light contained in it. This constituent of the beam is eliminated by passing the light through a nicol and from the setting of the latter it is possible to calculate the desired fraction. There still remains an arbitrary element, the angle subtended by the source of light, and since this is so the author takes the angle through which the nicol must be turned from a certain setting as a convenient, though not an absolute, measure of the gloss. On this scale blotting paper reads 20 degrees; Solio, 50; ordinary magazine paper, 25 to 40. An absolute determination of the gloss as above defined can be got by using two different angles of incidence.

The instrument, the glarimeter, is portable and strong. Only 15 or 20 seconds are needed for a determination, and darkening the room is not necessary. Its use is not limited to paper. The gloss of paints, varnishes, textile fabrics and finishes can be investigated with it. Its special employment seems to be for controlling the calendering process of papers.

The instrument in its general outlines was devised some years ago, but the famine of optical parts during the war delayed its completion. Keisel, in Germany, appears to have developed a similar instrument independently, though later.

G. F. S.

THE LUKENS ODOMETER.

HENRY R. TOWNE and COLEMAN SELLERS, JR.

Members of the Institute.

At the Stated Meeting of the Institute, held on the evening of Wednesday, April 20, 1921, Mr. Henry R. Towne, of New York City, member of the Institute, presented to the Institute for its collections an apparatus for measuring the distance traveled by vehicles, made by Mr. Isaiah Lukens, early in the last century. Mr. Coleman Sellers, Jr., Vice-president of the Institute, gave an account of the life and work of Mr. Lukens; and Mr. Henry R. Towne, in presenting the odometer, described its construction and operation.

Mr Sellers said:

There will be presented to the Institute this evening, by Mr. Henry R. Towne, of New York, an odometer, constructed in the early part of the last century, by Isaiah Lukens, an early member of the Institute.

It will add, perhaps, to the interest attaching to this piece of apparatus to consider for a few moments, the character and attainments of the maker. Unfortunately, there does not appear to be very much printed material relating to the life of Isaiah Lukens. In the December number of the FRANKLIN INSTITUTE JOURNAL, 1846, there was a brief biographical sketch, very appreciative of Mr. Lukens, but not accurate in respect to his genealogy.

Isaiah Lukens was descended from Jan Lucken, whose family was one of the thirteen families who followed Daniel Pastorius to Pennsylvania from Crefeld, in lower Germany, landing in Philadelphia October, 1683.

It will be recalled that when William Penn was arranging for the settlement of his colony, he entered into negotiations with a body of German Menonites, whose religious views corresponded in many respects with those of the Society of Friends, or "Quakers" as they were derisively called. These peace-loving Germans, mostly people of substance were seeking a land where they would be free from persecution. They purchased from William Penn a tract now forming that part of Philadelphia known as Germantown, comprising, it is said, 15,000 acres, which some authorities say was afterward increased to 25,000 acres. The price paid was 5 shillings for 100 acres, or 38 pounds sterling for the whole 15,000 acres.

Some of the descendants of Jan Lucken removed to Mont-

gomery County, where they were generally remarkable for their skill and ingenuity. One of them, John Lukens, was Surveyor General of the Province, and was noted for his ability as a surveyor and mathematician. Seneca Lukens, the father of Isaiah, was a farmer at Horsham, in Montgomery County, who also carried on the business of a clock and watchmaker, and it was from him that Isaiah, who was born in 1779, acquired his knowledge of the art. On coming of age, he joined his father in business.

His country environment, however, did not afford him full scope, and about 1811 he removed to Philadelphia, where he soon established a reputation for his mechanical and scientific ability and made a prominent place for himself in the community, especially among those who, like himself, were interested in the development of natural science.

Probably Mr. Lukens came most prominently before the general public in those early days through his exposure of the fraudulent character of the so-called Redhoeffer perpetual motion. In 1812, Charles Redhoeffer constructed a machine which appeared to run without the application of any power, the real motive power being so adroitly concealed that large numbers of people were deceived. The Legislature of Pennsylvania actually appointed a commission, "to make a strict examination of the machine invented by Chas. Redhoeffer, and to make a specific representation respecting its alleged importance as the public expectation required." Nathan Sellers and Oliver Evans, the inventor of the high-pressure steam engine, were among the members of this commission. The commissioners were unsuccessful in exposing the fraud, as they were not permitted to probe too deeply; but they were none the less convinced that the device was fraudulent. It was said that Mr. Lukens, who was present, remarked that the motion of the machine was very indicative of a crank turned by hand power. He then proceeded to make a model along the lines of the Redhoeffer machine; but operated by a concealed spring. This model is in the collection of The Franklin Institute and is one of its most valued possessions.

Having made some improvements in certain surgical instruments which had been invented by a surgeon in Paris, Lukens visited Europe for the purpose of introducing his inventions. He was unsuccessful in this effort but secured employment as a clock and watchmaker, and specialized in the making of chronometer

springs and surgical instruments, in which he was very successful owing to his methods of tempering steel. He remained in England and France for about three years, when he returned to Philadelphia.

In 1828, he was employed in making clocks for public buildings in Philadelphia and elsewhere. Among those constructed for Philadelphia buildings may be mentioned the clock in Independence Hall, the Bank of the United States, the Philadelphia Bank and others, all of which were excellent pieces of apparatus. On account of his ability as a mathematician he was assigned the duty of making the necessary observations for correcting the city time. These observations were made with his own transit instruments and were of great value for the regulation of marine chronometers.

He was active in the establishment of The Franklin Institute and was chosen as Vice-president at the first election held by the Society, which was on the 16th of February, 1824. From that time until his death on the 12th of November, 1846, he was an energetic and useful member. The writer of the memorial in the Journal speaks of him as follows: "He was eminently useful; freely yielding his time and attention to the various duties which he was required to perform—and by his advice and assistance aiding and supporting the Institute in its various operations for the benefit of science and the useful arts. His punctuality, diligence and intelligent service on committees appointed for the investigation of many important subjects will long be remembered among us, while the kindness of his disposition, and the many amiable and excellent qualities of heart and mind endeared him to an eminent degree to those who enjoyed opportunities of familiar intercourse with him."

Throughout his connection with the Institute, he was chairman of the Committee on Inventions, which later became the Committee on Science and the Arts.

Isaiah Lukens was not merely a highly skilled craftsman. As the record shows, he was really a scientific man of considerable ability and wide versatility. Besides dabbling in astronomy, he was interested in mineralogy and also, as his memorialist says: "Felt a lively interest in the progress of useful improvements, and from his general knowledge and habits of close investigation was well qualified to judge of their merits—encouraging such as were deserving, by his approval and influence."

As an example of Isaiah Lukens' wide interest in scientific matters, he constructed from a written description, two magneto-electric machines, and one of these is in the possession of The Franklin Institute. The original apparatus invented and constructed by Joseph Saxton was exhibited and described at a meeting of the British Association for the Advancement of Science in 1833. In 1834 it was brought to the atttention of the Institute by Prof. Alexander D. Bache, at which time one of the Lukens' machines was used to illustrate the subject.

He was a member of the American Philosophical Society and of the Academy of Natural Sciences.

Throughout the ninety-seven years of its life, The Franklin Institute of the State of Pennsylvania has been fortunate in having in its membership men of great ability who have devoted themselves unselfishly to the work of the Institute, and among these, not the least, was Isaiah Lukens.

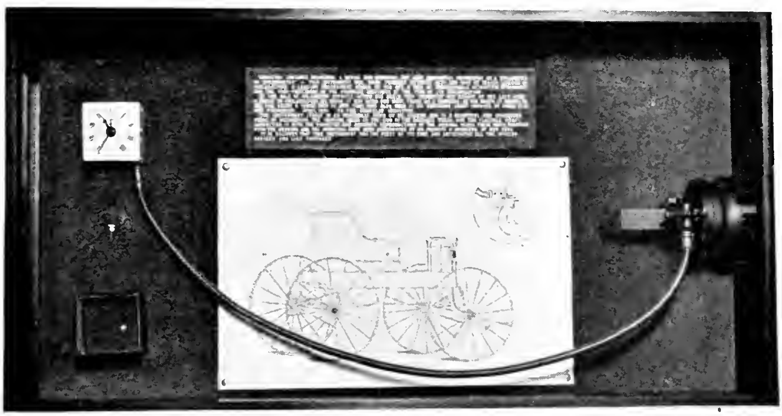
Mr. Towne, in presenting the apparatus, said:

The men who are regarded as dreamers and visionaries by their own generation are often recognized as prophets or discoverers by later generations. A "dreamer" in this sense was the Marquis of Worcester, whose "Century of Inventions," published about 250 years ago, described machines and processes, most of which were unknown and unattainable in his day, but many of which have since become realities. The most notable "discoverer" in this sense probably was Leonardo da Vinci, who lived some 400 years ago, who was one of the greatest of the Italian painters, and who is best known as such, but who was equally great as an engineer, administrator, and inventor. He not only conceived inventions but also made many drawings and practical models embodying them, and thus anticipated by several centuries some ot the great achievements of our day.

Philadelphia has had its "dreamers" and inventors, and still better, its men of achievement. It is the birthplace of many of the important advances in the mechanic arts made during the past century, and the roll of its citizens who have made notable contributions in this field is a long one. Among these names, that of Isaiah Lukens may properly be included, as is evident from the very interesting sketch by Mr. Sellers of his life and achievements, to which we have just listened.

The "Odometer," which it is my pleasure to present to The Franklin Institute this evening, is an excellent example of Mr. Lukens' skill, both as a designer and a mechanic, having been made, as I believe, by his own hands. The instrument itself (in the left-hand upper corner of the case) has continuously been in the possession of my father or myself since Mr. Lukens' death. The driving gear on the wheel-hub, and the flexible shaft connecting it with the Odometer, are accurate reproductions of the originals, made, from my description, by Mr. Francis H. Richards, of New

FIG. 1.



The Lukens Odometer.

York, who generously has contributed these parts and the effective mounting of the exhibit. The inscription within the case reads as follows:

"Odometer" (Distance Measurer). A device now commonly, but less accurately, designated as a "Cyclometer" or "Speedometer." This instrument was made, probably between 1830 and 1840, by Isaiah Lukens, of Philadelphia, a leading instrument maker of his day, a man of considerable scientific attainment, and the Vice-president of The Franklin Institute at the time of its organization.

At the sale of Mr. Lukens' effects, after his death, this "Odometer" was bought by the late John H. Towne, of Philadelphia, by whom it was used for many years on a carriage. At his death it passed to his son, Henry R. Towne, now of New York, who also used it on carriages about 1880-90, by whom it is now presented (April, 1921) to The Franklin Institute.

The instrument itself is as originally made by Mr. Lukens, and is a

beautiful and ingenious piece of mechanism. The driving gear on the hub of the carriage wheel, and the flexible shaft connecting it with the "Odometer," are accurate reproductions of the original parts. These parts, together with the drawing and the mounting, have been contributed by Mr. Francis H. Richards, of New York.

It is believed that this instrument was the first of its kind, and anticipates all the modern devices for like purposes.

The use of a wheel by surveyors for measuring distances, especially for road maps, is very old. The names usually applied to it were "measuring wheel" or "perambulator." The wheel was provided with a single shaft, by which it was pushed or pulled over the road to be measured, its circumference usually being either 10 feet or some aliquot part of a mile. In some cases it had attached to the shaft a counter to indicate the number of revolutions or the distance covered. This crude device was developed by Mr. Lukens into a form which embodies all of the essential elements of the "cyclometers" and "speedometers" of the present day, namely, the Drive, the Transmission, and the Recording Instrument, the latter being cumulative and resettable. The mechanism of the Recording Instrument is ingenious and beautifully simple. It consists only of three spindles and five worms, all of the latter being "skewed." It has three hands, one revolution of each of which shows respectively 1 mile, 10 miles, and 100 miles, its cumulative reading thus covering 111 miles—an ample provision for horse-drawn vehicles.

Its adaptation to any vehicle was effected by providing the hub gear with the proper number of teeth. For example, if the front wheel of the vehicle were 3′ 6″ in diameter (its circumference thus being almost exactly 11′), the hub gear should have 11 teeth, as in this model, and would make one revolution for each seventeen revolutions of the wheel. The ratio of this gear to the wheel required to give absolute accuracy is 17.14, and the error resulting from the ratio of 17 to 1 is thus 43½ feet per mile, or .00825 per cent.

I take great pleasure in presenting to the Institute this interesting example of the clever work of one of Philadelphia's early scientists and mechanicians, and thus returning the Lukens Odometer to its birthplace.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE SETTING AND MELTING POINTS OF GELATINE.[1]

By S. E. Sheppard and S. S. Sweet.

[ABSTRACT.]

POSSIBLE definitions of "melting point" and "setting point" of jellies are discussed. It is suggested that theoretically these would be defined incidentally by the temperature at which the "time of relaxation" became infinite, the viscosity remaining finite. Practically it is agreed that they may be arbitrarily defined by standardized exceptional conditions. An apparatus for determining both "setting points" and "melting points" is described, in which use is made of an electrically controlled intermittent air-current at small constant pressure. Characteristic curves with concentration of gelatine as abscissae are given in comparison with jelly strength curves, and the results applied to grading commercial gelatines.

Stones Absorb Water. (*U. S. Geological Survey Press Bulletin No. 472,* June, 1921.)—Stone is by no means impervious to water. Some kinds, notably coarse sandstones, hold a large percentage. Even marbles absorb considerable quantities. The absorptive capacity of limestones ranges from 7 per cent. or more down to practically zero. Porous limestones, in which the pore space ranges from 10 to 15 per cent., will absorb from 4 to 6 per cent. of water, whereas semicrystalline and crystalline limestones or marbles have lower percentages of pore space and of absorption, such marbles as those from Vermont, Tennessee, and Georgia being almost non-absorbent. Pumice stone, which is usually lighter than water owing to its great amount of pore space, will absorb large quantities of water; obsidian and volcanic glass, which are of the same chemical composition as pumice stone, but several times heavier than water, will absorb none. Quartzite, granite, and the numerous eruptive rocks are practically impervious to water.

* Communicated by the Director.

[1] Communication No. 110 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. Eng. Chem.,* 1921, 13, 423.

Henry A. Bumstead. LEIGH PAGE. (*Am. Jour. Science,* May, 1921.)—On the last day of 1920 American science suffered a notable loss by the death of H. A. Bumstead, who died on the train while on his return from a meeting of the American Physical Society. While a mere stripling he fell under the spell of the brilliant and erratic Rowland at Johns Hopkins, while later he became the friend of J. Willard Gibbs.

His papers dealt with the application of Maxwell's equations to electric waves, with electro dynamics. He investigated the radioactive character of Connecticut well water and of soil water and from this deduced the atomic weight of radium emanation. In the Cavendish Laboratory he studied the heating effects of X-rays on metals. Later the delta and the alpha rays claimed his attention. The Sloane Laboratory at Yale is a monument to his foresight. During the war he was Scientific Attaché to the British Embassy, and at the time of his death he was at the head of the National Research Council. Writer, investigator, lecturer and college teacher he wielded an influence that will long be felt in the scientific life of the United States. G. F. S.

The Structure of the Helium Atom. I. LANGMUIR. (*Phys. Rev.*, March, 1921.)—Bohr's models of the hydrogen atom and of the positively charged helium ion are now widely accepted. Since the fine structure of the lines of these two elements can be explained in detail from the models, there is good reason to hold that the models correspond to structural facts. Bohr's model of the helium atom, however, is not so successful in furnishing an explanation of the spectrum or of other properties. He assumes that the two electrons revolve about the central nucleus in one circular orbit. Langmuir first tries a model in which the two electrons rotate in the same direction in different circular orbits, whose planes are equally distant from the nucleus. Consideration shows that this type of structure must be discarded, since it turns out to be unstable. A second type is then suggested in which the two electrons move in the same circular orbit, but each traverses somewhat less than a semi-circle and keeps to its own half of the circle. The electrons move along the circle so that they would meet were the motion to continue. As they approach their mutual repulsion retards their motion. They stop and turn back and go through the same change of velocity near the other end of the semi-circle. They never get to the very end.

For this second type the ionizing potential comes out equal to 25.62 volts, which agrees well with the results of two experimental determinations by different observers, *viz.*, 25.7 and 25.5 volts. Other tests must be applied, but at least the new type of helium atom is worthy of serious consideration and may on closer inspection and longer acquaintance prove itself capable of explaining all that remains to be explained. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

ALEXANDRIA SENNA CULTIVATED IN INDIA.[1]

By C. J. Zufall.

[ABSTRACT.]

ALEXANDRIA SENNA from the Sudan has been found to be adulterated with the leaves of *Cassia obovate*, or dog senna, as well as with Arabian or Mecca senna. This form of adulteration is difficult to detect in grades known as "broken," "half leaf," or "siftings;" in fact, it is difficult to detect the presence of any foreign leaf in these grades if the adulterant is broken. Any form of adulteration is readily noticed, however, in the cultivated, hand-picked Alexandria senna from India because it consists almost entirely of whole leaves.

SOME OBSERVATIONS OF CORN MEAL IN STORAGE.[2]

By L. H. Baily and C. Thom.

[ABSTRACT.]

FOUR lots of corn meal ranging in water content from 12.5 per cent. to 16.6 per cent. were stored under well-ventilated conditions from April to August. One-half of each lot was unbolted meal. Subsamples of each lot were stored in glass in the laboratory.

In the well-ventilated samples the acidity, as determined by the method of Black and Alsberg at the close of the experiment, ranged from 53 to 65 degrees. No sourness, rancidity, lumpiness, moldiness or mustiness was detectable. Baking tests from each lot produced an acceptable product.

In the samples in glass, moldiness was evident in all samples having a moisture content of 14 per cent. or higher. None of these samples were in a merchantable condition.

*Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Pharm. Asso.*, 1921, **10**, 185.

[2] *Operative Miller*, 1920, **25**, 368.

STUDIES IN NUTRITION. VI. THE NUTRITIVE VALUE OF THE PROTEINS OF THE LIMA BEAN, *PHASEOLUS LUNATUS.*[3]

By A. J. Finks and Carl O. Johns.

[ABSTRACT.]

A DIET of cooked lima bean meal supplemented with 0.3 per cent. of cystine, together with the other necessary non-protein dietary ingredients, furnish adequate protein for the normal growth of albino rats. A similar diet to which no cystine was added merely maintained the weight of the experimental animals. Growth did not occur if the diet consisted of either raw or cooked lima bean meal which was not supplemented with cystine, although the other non-protein dietary factors were added.

STUDIES IN NUTRITION. VII. THE NUTRITIVE VALUE OF THE PROTEINS OF THE ADSUKI BEAN, *PHASEOLUS ANGULARIS.*[4]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

RAW or cooked adsuki bean meal supplemented with cystine furnished adequate protein and water-soluble vitamine for normal growth. Similar diets without the addition of cystine enabled the albino rats to grow at only one-third to two-thirds of the normal rate. Comparable results were obtained with the isolated adsuki bean globulin.

Dinitrosalicylic Acid—a Reagent for Glucose. JAMES B. SUMNER and V. A. GRAHAM, of Cornell University (*Jour. Biol. Chem.*, 1921, xlvii, 5–9), recommend 3.5-dinitrosalicylic acid as a reagent for glucose. The sodium salt of this acid reacts with glucose in the presence of sodium hydroxide at the temperature of boiling water to form a highly colored soluble nitroamino compound. The reaction may be used for the colorimetric determination of glucose. The color with dinitrosalicylic acid is not given by acetone or creatinine, but may be given by uric acid, polyhydric phenols, and other reducing sugars under certain conditions. J. S. H.

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[3] Published in *Am. J. Physiol.*, 1921, 56, 205.

[4] Published in *Am. J. Physiol.*, 1921, 56, 208.

NOTES FROM THE U. S. BUREAU OF MINES.*

NATURE OF SHALE OIL OBTAINED FROM BUREAU OF MINES ASSAY RETORT.

By Martin J. Gavin and Lewis C. Karrick.

Many inquiries have been received as to the quality of oil obtained from the assay retort developed and used by the Bureau of Mines, when it is operated under conditions most suitable for producing the highest yields of oils.

Experiments in the bureau's laboratories indicate that the quantity and quality of oil obtainable with the retort from a given shale can be varied by varying the conditions of retorting. For purposes of comparison, distillation analyses were made of a Scotch commercial shale oil; oil obtained from Scotch shale in the assay retort; oils obtained from an oil shale from Soldier's Summit, Utah, by the assay retort at two and five-hour rates of retorting; and a sample of Pennsylvania crude oil.

(a) The oil from Scotch shale by the assay retort is somewhat superior to that produced in commercial operations in Scotland, except as regards unsaturation percentage. The difference in unsaturation percentage, however, is small.

(b) The oil produced from the Soldier's Summit shale by the assay retort is nearly equivalent to that made from Scotch shale both by commercial operations in Scotland and by the assay retort in the laboratory, except as regards percentage of unsaturation. This is a quite important point, as unsaturation percentage is an indication of the relative magnitude of refining losses. The Soldier's Summit shale oil apparently contains a higher percentage of paraffin wax than the other oils examined, as indicated by setting points of the crude oils and the percentages and setting points of the vacuum fractions.

(c) The five-hour retorting period produced a lower yield of oil than the two-hour run, but the quality of the oil produced in the longer period was somewhat better. The slight difference in

* Communicated by the Director.

quality is largely offset by the greater yield of the shorter run, and also by the actual saving in time, fuel, etc., in making a retorting test.

(d) The Pennsylvania crude is superior to the shale oils except in paraffin content, as indicated by setting points.

It is interesting to know that the best oils thus far produced in the laboratory from both Scotch and American shales have been made in the assay retort. In no case, by any retort thus far used in the laboratory, have oils been made from American shales that are fully equal in quality to Scotch shale oils. Tables showing the results in detail have been published in a recent paper.

QUANTITATIVE MICROSCOPIC DETERMINATION OF COPPER SULPHIDES IN PORPHYRY ORE.

By R. E. Head

In commercial plants and laboratories working on porphyry copper ores, it is frequently desired to ascertain the approximate proportions in which the copper sulphides and pyrite exist in the ore. Recently the writer had occasion to conduct such an analysis on an ore carrying chalcopyrite, chalcocite and bornite, besides pyrite. As chemical methods offered little possibility of yielding the desired information, a microscopic method was employed. The ore, in crushed condition, was prepared in small briquettes with sealing wax, the surface polished, the relative number and area of the grains of the different minerals in the polished surface determined under a microscope by use of a net-ruled micrometer disk, and the relative proportions of the different sulphides calculated by a modification of the Rosiwal method. This procedure gave the data desired. It offers interesting possibilities for use by metallurgists and chemists in affording approximate results for checking efficiency of flotation or other treatment plants, where chemical analyses are not available, and supplies useful information on the physical characteristics of the ores being treated. The method used is more fully described in a recent report issued by the bureau.

GASES FROM USE OF CARBON TETRACHLORIDE FIRE EXTINGUISHERS IN MINES.

By A. C. Fieldner and S. H. Katz.

Recent experiments with carbon tetrachloride fire extinguishers in the experimental mine corroborate the results of earlier laboratory tests, that the gases produced contain small quantities of irritating and poisonous gases which may be dangerous in closely confined places where the user cannot escape breathing the fumes. Hence care must be observed in the use of fire extinguishers of the carbon tetrachloride type in underground fire fighting. Details are given in a recent report of the experimental work which has been carried on at Pittsburgh.

Diathermy of Ice, Water and Steam. S. L. Brown. (*Phys. Rev.,* March, 1921.)—The radiation from an electric furnace was allowed to fall on a resistance element several feet away. When the stream of radiation changed the temperature of the element changed. This caused a change of resistance, which was easily measured. From a change in the resistance it was possible to calculate the change in the radiation received. First the unobstructed radiation from the furnace fell on the element, then a sheet of water was placed in its path. From the change of resistance was calculated the fraction of the radiation absorbed. When steam was tried care was taken that no condensation occurred. By varying the temperature of the furnace the radiation characteristic of different temperature intervals was investigated.

The per cent. of total radiation transmitted by a sheet of ice increases greatly as the temperature of the source rises. The same is true of water. It is quite striking that half a millimetre of water transmits only 26 per cent. of the radiation from a source at 1000° C. No absorption whatever was detected in the case of steam.

G. F. S.

Acoustics of Large Auditoriums. C. R. Fountain. (*Phys. Rev.*, March, 1921.)—Even after large plush curtains had been hung in the New City Auditorium, Macon, Georgia, the voice of a speaker on the platform was inaudible in the middle of the building. This is 200 ft. by 130 ft. by 60 ft. high, roughly boarded up with many cracks. The author expected to find reverberation, but was disappointed in this. The remedy was to erect an inner stage which directed the sound energy toward the audience with a minimum number of reflections. The dropping of a pin could then be heard anywhere in the building.

G. F. S.

The Chemical News in a New Form.—The following, from an announcement in a recent issue of the *Chemical News,* will interest all chemists. While many will regret the disappearance of the form and style that has been familiar for over half a century, yet the publishers are not to be criticized unfavorably for adapting the periodical to the changed conditions of the science of chemistry:

"After much discussion and enquiry it has been decided to make an alteration in the appearance, and also the title and contents of the *Chemical News*. . . .

"The great advances that have, within the last twenty-five years, been made in the domains both of chemistry and physics, and the fact that these advances have been largely absorbed in our national industries, has brought the *Chemical News* into the hands of manufacturers and merchants to a very much greater extent than in the past.

"We are, therefore, venturing to alter the latter part of the title to *Journal of Industrial Science* and to make an appropriate alteration to the title-page of the volume. . . .

"Firmly believing that we shall before long enter upon a period when the present state of unrest and agitation will give place to one of serious work and production, it is our intention to lose no time in contributing our mite to the increasing activity in industrial science. We shall greatly value any suggestions and criticisms upon the course we are taking." H. L.

Asbestos. (*U. S. Geological Survey Press Bulletin No. 474,* July, 1921.)—The art of weaving the mineral fibre in asbestos, which is ordinarily indestructible, was rediscovered at a comparatively late period of civilization. Woven asbestos was used in the ancient pyre to preserve the royal ashes. Charlemagne is said to have had a tablecloth made of asbestos and to have cleaned it by throwing it into the fire, which consumed the dirt, thus illustrating in a spectacular manner one of the most valuable properties of this material.

The fibre of the best grade of asbestos is beautiful and silky and has great flexibility, elasticity, and tensile strength. It can be spun into thread so fine as to run 225 yards to the ounce, and as it is incombustible as well as a non-conductor of heat and electricity and resists the action of most ordinary acids, its field of use is large. The possible applications of asbestos are far from fully appreciated not only by the general public, but by manufacturers who are in search of material for special uses to which asbestos may well be applied. Perhaps it is most generally used to make fireproof cloth for theatre curtains. It has been used also for making firemen's clothing. Everywhere in cold countries it is extensively employed for covering furnaces, boilers, and pipes to prevent loss of heat. Asbestos is a good insulator.

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BOOK NOTICES.

SOME MICROSCOPICAL TESTS FOR ALKALOIDS. By Charles H. Stephenson, Scientific Assistant, U. S. Bureau of Chemistry. Also including Chemical Tests of the Alkaloids Used, by C. E. Parker, Assistant Chemist, U. S. Bureau of Chemistry. 110 pages, 27 plates and a folding table of reactions, 8vo. Philadelphia, J. B. Lippincott Company.

This book comprises a very large amount of information; the collection involves much routine and laborious work. The plates each contain six photomicrographs reproduced by photogravure. We are told in the preface that the book is essentially the outcome of researches undertaken in 1907 for the purpose of obtaining microchemical tests for cocain, and the investigations were carried on until sixty-four different alkaloids were examined. It seems, however, that thirteen of these were of doubtful purity and have not been included in the work. Commendation must be given to the authors for their careful work, and for the general excellence of the plates. It may be, however, a question as to how far such results are of value to the professional toxicologist or pharmaceutic analyst. These tests were made with essentially pure samples, but in actual practice, especially in toxicologic work, unknown impurities are apt to be present and confusion arise from such conditions. It may be better in general for the analyst to prepare his own specimens from known substances and compare them with the crystals obtained from the material under examination. Of course, there is a danger here, inasmuch as the chemist who should be examining the contents of a stomach for strychnine would not like to have a solution of any strychnine salt near his working table, but that difficulty can be met by carrying out the comparison in some other place. Strychnine and brucine are mentioned as two of four alkaloids that give the greatest range of crystalline precipitates, and they are among those that give the most characteristic color tests.

It is interesting to compare the plates of this book with those of Doctor Wormley's Microchemistry of Poisons. The plates in that work are all steel engravings made by Mrs. Wormley, and many of them are marvels of drawing. Photomicrographic processes have rendered such laborious work unnecessary. It is to be noted that probably interesting results could have been obtained by the use of polarized light and also by plain light with color screens. No information is given as to the methods of making the photographs. The plates and text are well printed, but the paper used for the text is unnecessarily heavy and the type unnecessarily large. It is, indeed, a question why this work should not have appeared as a government bulletin.

HENRY LEFFMANN.

AMMONIA AND THE NITRIDES, WITH SPECIAL REFERENCE TO THEIR SYNTHESIS. By Edward B. Maxted, Ph.D., B.Sc., F.C.S. 18mo., viii, 112 pages, contents, index and 16 illustrations. Philadelphia, P. Blakiston's Son & Co. $2.00 net.

Nitrogen used to be considered as the type of the indifferent element, for even gold and platinum, notwithstanding their high resistance to the action of the air, were known to form a large series of compounds of great stability, while except as to the organic substances, the nitrogen compounds were chiefly noted for their instability. The discovery of the elements of the zero group displaced nitrogen from its position, and, in truth, the book before us shows that nitrogen has much chemical activity if it is given a chance. H. E. Armstrong, years ago, suggested that nitrogen might exist in an allotropic form, basing his views upon the large number of comparatively stable organic compounds, and recently, Strutt (now Lord Rayleigh) has obtained evidence of marked increase of the activity of free nitrogen under the influence of electric discharges. An account of these experiments is given by Dr. Maxted.

The chemist who has not paid attention to the field of the science will certainly be astonished at the large number of nitrogen combinations in the inorganic field. Of the numerous elements that are commonly regarded as essentially inorganic in their relations, fluorine seems to be the only one that is not mentioned as forming a nitride. As might be expected, nearly half of the book is devoted to the ammonia synthesis, a reaction that has been the subject of most extensive investigation, and which seems to have had a profound influence on the world's history, for it has recently been asserted on good authority, that if the Germans had not perfected the Haber process for producing ammonia, they would have been compelled to give up the fight in about a year, as the British blockade would have cut off the supply of nitrates, and left them without means for producing the modern high explosives.

The book is crowded with information along lines not presented in the ordinary text-books, or even in technologic works, and is a striking instance of the high specialization in modern science.

HENRY LEFFMANN.

MEMOIRE SUR LA CHALEUR, par MM. Lavoisier et De Laplace. 18mo., paper bound, 78 pages, two full-page plates. Paris, Gauthier-Villars et Cie, 1920.

This is another number of the series of reprints of the works of distinguished scientists of former years, the general title being "The Masters of Scientific Thought." Such essays are scarcely subjects of criticism, for the world's judgment on these scientists has long since been established, and they are now fully honored for their services. The essays make interesting and profitable reading, even though they bring no new information to the student, indeed, they sometimes contain statements now recognized as erroneous. The present work is a reprint of a paper published by the *Academie des sciences* in 1780. It is interesting to note the preliminary discussion on the nature of heat. The two theories, respectively, that heat is a substance diffused through all space penetrating all matter, and that it is due to motions of particles of matter, are presented, but the authors do not attempt to decide. The fact that the first theory has gone out of vogue suggests that future physics may dismiss equally to oblivion the theory of the ether, which is now so prominent in our text-books.

The book is very easy reading, but is printed on poor paper. The calorimeters used in the investigation are shown in detail in two fairly good plates. HENRY LEFFMANN.

LA PHYSIQUE DES RAYONS *x* per MM. R. Ledoux-Lebard et A. Dauvillier. 8vo., vii, 435 pages, index, 10 full page plates, numerous illustrations. Paris, Gauthier-Villars et Cie.

In this elaborate treatise on the subject of the X-ray we have a vast amount of detail, both practical and technical, and an introduction by de Broglie whose remarks may be conveniently taken as a general description of the nature and purpose of the book. The rôle played by X-rays in physics and in medical sciences continues to widen. It will also enter very soon into industrial applications. Unexpected discoveries have completely made over, in the last six years, our knowledge of this branch of physics, and, until the present time, no French work has presented in a complete form the most recent state of that knowledge. This work of MM. R. Ledoux-Lebard and A. Dauvillier has come to fill the gap. It will permit those who read it to follow the already considerable data that have been accomplished in recent progress, but it is not merely a chapter, a little scanty of the science which is about to take a new life, or merely a corner, a little dark, which has been cleared up and illuminated, for the book is a good deal more than that. The questions of which this work treats are in course of passing to the first rank of particular interest of modern physics. Why is it that the properties of the X-rays and of spectral analysis have acquired so important a bearing? It is essentially because it is a question of phenomena of high frequency, and that these very rapid periodical movements seem to be regulated by hitherto unknown and quite remarkable laws. The most salient fact, that which strikes us at the beginning, is the primary part played by the normal suc-

cession of the elements, that is to say the classification of simple bodies in the order of their increasing atomic weights. We cannot study the X-rays without studying chemistry at the same time, and without having to take up, indeed, a special chemistry, that of the simple substances. Everything in this domain is remarkably continuous and oriented. As soon as one sets the elements, according to their natural sequence, assigning to each a serial number, an integral number of necessity, this serves to fix completely a part played by the element considered with reference to the X-rays. No other department of physics offers anything comparable. We find nowhere an association as general and as harmonious. This natural order of the elements should, therefore, appear as fundamental to whoever wishes to study profoundly the rays of high frequency. But there is another point equally worthy of consideration, the law of Planck–Einstein or the relation of *quanta,* which binds the frequencies v to the energies W put in play by the relation

$$W = h v$$

in which h is a universal constant.

Perhaps all this will seem at first view a little ambitious and too far from practical application. This is not so. Certain experimental data new postulates, precise and directly utilizable, abound in the chapters of this book. All physicists, whatever may be their inclinations, will be interested in the results of experiments so striking as described in these pages, while the specialists will find there extended developments and abundant presentation. As far as regards those who have particularly in view the medical applications, all are convinced to-day that there can be no progress in the application of X-rays except in basing on rational data scientific and precise, that is to say, on profound knowledge, qualitative as well as quantitative, concerning the physical properties of the force utilized. This knowledge can be obtained only by a serious and complete study. A treatise such as the one before us will be, therefore, indispensable.

HENRY LEFFMANN.

HISTORICAL REVIEW OF THE OBJECTS, ORGANIZATION AND ACTIVITIES OF THE CHEMICAL ALLIANCE, INC., DURING THE WORLD WAR, 1917–1919. 8vo., 82 pages.

The data presented in this book have been brought together in the present form at the request of the Historical Bureau of the General Staff, U. S. War Department. The Chemical Alliance was an outgrowth of the Committee on Chemicals of the Advisory Commission of the Council of National Defense, which latter was created under an act of Congress, approved August 29, 1916.

The text gives minutes of the meeting of the Council of National Defense, and the organization of the Chemical Alliance, which it appears, was primarily formed at the request of the Department of Commerce for the handling of foreign pyrites. This was in the latter part of July, 1917. The organization, however, was an alliance of all branches of chemical industry and was active in dealing with all problems of a chemical char-

acter growing out of the conditions of war. These problems had far-reaching relations for labor questions and draft exemptions were involved.

The data given are therefore, quite interesting.

HENRY LEFFMANN.

COKE-OVEN AND BY-PRODUCT CHEMISTRY. By Thomas Biddulph-Smith, F. C. S. Gold medallist, Coke-Oven Managers Association. x-177 pages, index, 62 illustrations and 7 folding plates, 8vo. London, Charles Griffin & Co., Ltd., and Philadelphia, J. B. Lippincott Company, 1921.

The importance of the chemistry and engineering of all processes relating to tar is constantly growing, and it is apparent that all great nations must cultivate a scientific knowledge of these industries. The incidents of the last war have brought home to all thinking persons the many-sided character of such procedures.

The book in hand is a comprehensive account of the chemistry of coke-oven tar and its treatment up to the extraction of the so-called "crudes," which are described in both their commercial forms and pure condition. Processes of analysis are given in detail. The work is very largely illustrated and the descriptions are not confined to the tar alone nor to the hydrocarbons obtained from it, but other by-products are considered.

Beginning with a statement of standard methods for the analysis of the coal, including tests of coking qualities, the subject of the incondensed products of distillation is taken up. Eighteen pages are devoted to this, followed by a brief statement of the analytic method for flue-gases. The testing of the several fractions of the tar distillations then follows. The ammonium sulphate plant is not overlooked.

The work is essentially, as its title indicates, a compact and very useful summary of the principal chemical problems concerning coal-tar.

The numerous illustrations and graphic representations of data on large plates add greatly to the value of the book. A list of elements, atomic weights and symbols and a chapter on the preparation of standard solutions are appended. The atomic weights are those of 1918, but a revised list was published in 1920, probably, however, too late for incorporation in this work.

HENRY LEFFMANN.

THE CHEMICAL EFFECTS OF ALPHA-PARTICLES AND ELECTRONS. By Samuel C. Lind, Ph.D., Physical Chemist, U. S. Bureau of Mines. 8vo, 182 pages, including all parts, 8 illustrations and 22 tables. New York, The Book Department, The Chemical Catalog Company.

This is one of the American Chemical Society's Monograph Series, arrangements for the publication of which were made in 1919 at sessions of the Interallied Conference of Pure and Applied Chemistry. The volume in hand, the second to be issued, treats of an extremely abstruse subject, and one of very recent development, undoubtedly still in its infancy. The phenomena of radio-activity are among the most striking of all phenomena in physics, and have led to great changes in the conception of matter and force. In several respects this book shows original features. The paging includes

the title page and runs to the last page of the index. The old-fashioned Roman paging for the preliminary matter is discarded and can be well spared. Like black-letter, it was a product of the perverse ingenuity of the mediæval writers. Then the title of the publishing company is printed in the new spelling, "catalog," which is also an acceptable change. The general make-up of the book is excellent. Although the Interallied Conference in its earlier meetings did not include Germany among the eligible nations, it is interesting to note that the only four comprehensive works, quoted by title in the preface as specially available for data on the subject of the monograph, are German. It is also worthy of note that the Board of Editors, twelve in number, contains no Philadelphia chemist.

Radio-activity is exhibited by only few elements, those that have the property well marked, radium and thorium, being noted as having the highest atomic weights in the list. It appears, however, that a very rare element, actinium, concerning which little information is at hand, has also this property, and that feeble powers have been discovered in potassium and rubidium, which emit beta rays. Is it possible that our inability to detect such properties in all elements is due to lack of sufficiently delicate methods? It is well-known that the introduction of highly delicate tests in general chemistry has resulted in the detection of traces of substances formerly unsuspected. Most of the metallic elements discovered during the past half-century were found by means of the spectroscope. The combination of this instrument with the sensitive plate has still further widened our information. Perhaps substances may be found that are so sensitive to radio-active emanations that all elements will be taken into the list.

The wealth of material included in the work is too great for brief summary. Glancing over its pages, the chemist feels as if the independence of his science was being threatened, and that it may be at no distant day a mere phase of physics. However, in practical, sanitary and industrial relations the balance and burette will be likely to hold a prominent place, and much interesting work be done and much benefit given the world without close attention to the more abstruse uses of radio-active phenomena. The everyday chemist has seen his importance challenged more than once, and still holds a prominent position. When bacteriology was beginning its spectacular development, Koch said that chemical analysis of water would soon become merely academic, but it is still a feature of all investigations of the applicability of a given supply to household and industrial purposes.

It will be noted from the title that the work does not include the whole field of radio-activity. The preface states that it is the object of the monograph to collect the experimental data and as far as possible to present the collection in such a way as to emphasize the relations between the chemical effects of the material and of the photochemical radiations. The field of photochemistry proper has been presented only to a limited extent, and similarly the subject of radio-activity has been introduced only so far as to make clear the principles and technic involved in the use of such substances as sources of radiations for producing the chemical effects described.

To the majority of chemists, especially teachers, the most interesting chapter will probably be that on Isotopes. The discovery that many of our so-called elements are really composed of closely allied substances has startled most of us perhaps more than the discovery of the X-ray and radio-activity. It is stated that, so far, hydrogen, helium, carbon, nitrogen, oxygen, fluorine, phosphorus and arsenic have given no evidence of compound nature, a fact which accords with the whole-number character of their atomic weights, but boron, silicon, neon, chlorine and bromine have been found to consist of two forms, and krypton and xenon of several. It seems likely that when this problem is worked out the significance of the fractional atomic weights will be known, and Prout's whole-number theory will come into play.

The general introductory informs us that the series of monographs is part of an effort to establish a literature typically American and without primary regard for commercial considerations. Such a purpose will appeal strongly to the majority of chemists in the country, and it is to be hoped that the effort will be successful. Monographs, such as the one before us, are of the greatest use to the mass of profession, because they present in a compact form the results of years of investigation, and summarize literature which is mostly inaccessible to the larger proportion of workers.

HENRY LEFFMANN.

CHEMICAL REACTIONS AND THEIR EQUATIONS. A guide and reference book for students of chemistry. By Ingo W. D. Hackh, Ph.D., A.B., Professor of Biochemistry, College of Physicians and Surgeons of San Francisco. viii-138 pages, including contents and index, 18mo. Philadelphia, P. Blakiston's Son and Company, 1921. $1.25 net.

A summary of the general principles of stating and solving reactions with a great deal of data concerning the stoichiometric problems. Although a small volume, the compactness of the text is such that a very large amount of information has been included. Many small text-books on elementary chemistry have been published, but the work before us is somewhat different in scope and character from the majority of them. It begins, of course, with definitions of the fundamental terms, "atom," "molecule," "ion," and presents the different forms in which the same symbol is used to express the conditions of these three terms just noted. Each chapter is followed by a list of questions. How far this latter plan is beneficial to the student is matter of doubt. If many set questions are provided, students and even teachers may fall into a routine method of using them, instead of allowing the questioning to grow out of the study of the text itself. In connection with the discussion of valence, the negative and positive valencies are indicated by the respective signs placed before the number representing the degree of valency. Thus, hydrogen in the ordinary acids is designated as a monovalent positive and represented by $+1$, while in such compounds as sodium hydride its valency is considered negative and represented by -1. There seems to be a danger of confusion in this method. Most students of elementary chemistry are pursuing the science in association with some departments of mathematics, especially algebra, and such forms of symbols are likely to give trouble. The

usual and better method is, however, followed in the actual equations given, in which the plus and minus signs are duplicated as exponents, using the number of signs equal to the valency of the elements.

The book is practically limited to a study of chemical actions as such, not being an introduction to descriptive or physical chemistry. It is a useful addition to the elementary text-books.

HENRY LEFFMANN.

ÉTUDES ÉLÉMENTAIRES DE MÉTÉOROLOGIE PRATIQUE. By Albert Baldit, president of the Meteorological Commission of the Haute-Loire. 8vo, ix-339 pages and table of contents. Paris, Gauthier-Villars et Cie, 1921. Price, unbound, 15 francs.

Monsieur Baldit was charged with some of the most responsible meteorological duties for the French army during the World War. His interesting book tells in detail what these duties were, and what personnel and instrumental equipments were essential to their proper performance. The chief value of the book therefore is to the military service. But it is also helpful to those who wish to make weather predictions for civil life more comprehensive and exact.

The first 139 pages deal most helpfully with the organization of an efficient meteorological service for military needs. The kinds of stations, their instrumental equipment, their personnel, the kinds of observations to make and the forecasts to issue are all discussed at length. It is even urged that aeroplanes be used for obtaining some of the free air data, and as scouts to actually spy out the weather conditions in all directions from great altitudes.

The second portion of the book, pages 140 to 181, deals briefly with some of the relations between the temperature, pressure, density and altitude of a mass of air; and with the dependence of winds on pressure gradients, latitude, and rotation of the earth.

This is a branch of meteorology in which one often has to chose between mathematical elegance and physical clearness. In this case the former alternative was chosen—a wise enough choice for the properly equipped reader, but disconcerting, perhaps, to those of little or no training in the field of mathematical physics.

The third portion, pages 182 to 335, is devoted to the specific problems of weather forecasting. Several "rules" are given, based on pressure distribution, temperature distribution, winds, clouds, and other sources of information. This section of the book, however, is disappointing; not because of any shortcomings of the author, but because weather forecasting is not an exact science. It is headed that way, for all weather phenomena have their physical causes, but it has a long way yet to go.

All meteorologists can read this book to advantage. The military meteorologist must read it.

There is no index, a really serious blemish which, however, a little time and patience can remove from the next edition.

W. J. HUMPHREYS.

Tables of Refractive Indices, Vol. II. Oils, Fats and Waxes. Compiled by R. Kanthack. Edited by J. N. Goldsmith, Ph.D., M. Sc., F.I.C. 295 pages, 8vo. London, Adam Hilger, Ltd. Price £1 5s.

The firm of Adam Hilger, Ltd., has long been favorably known for instruments of precision of highly specialized types, especially in the field of applied optics, and has begun to supplement its manufactures by the publication of reference works upon these topics. The volume before us is a compilation of many thousands of data on the subject of the refractive indices of a class of substances that are of the greatest importance in both industrial and physiologic chemistry. The compiler has searched the literature with great zeal, and his gleanings are set forth in carefully arranged tables. Nearly five hundred references are given covering all important journals and books. Doctor Kanthack has, however, not sought to put on record every datum in regard to a given oil. The determination of refractive index has great practical value. It is more rapidly made than specific gravity and is regarded as a more accurate measurement. The tables contain four columns, showing respectively the temperature (C) at which the determination was made, the values of n_D and B , and an index number which refers to the original sources of the data. The instruments employed in the examinations are the Abbe refractometer and the butyrorefractometer.

A work like this saves the analyst a great deal of time and trouble, for it presents in compact form, easily accessible, a vast amount of data of every day use. The substances are arranged in alphabetical order; the bibliography is numbered consecutively, so that a reference to the source of any datum is, as noted above, easily made.

The mechanical execution of the work is excellent, and it is a valuable addition to the literature of the subject. Henry Leffmann.

Les Mouvements des Végétaux. Du Réveil et du Sommeil des Plantes. Par René Dutrochet. 121 pages and illustrations, 18mo. Paris, Gauthier-Villars et Cie, 1921.

This is another volume of the series of "Masters of Scientific Thought," which this well-known Paris publishing firm is issuing. The general character of the series has already been set forth in this journal. The question of the consciousness of plants has been answered during the past always in a firm negative, but biologists at the present are, perhaps, not quite so sure on the subject. Of course the first step in the discussion will be to determine what is meant by consciousness, possibly still an unsolvable problem. The distinction between reason and instint has not yet been definitely made, and the distinction between free will and determinism still engages the energies of the theologians and psychologists. The work before us does not enter into these questions, but records a large number of experiments with plant forms, especially the phenomena generally known as the "sleep of plants." Dutrochet's family suffered financially in the French Revolution. His father was an "emigré" and the estates were confiscated. A brief account of the life of the scientist is given in the introduction.

It is interesting to note that though the investigations were made nearly seventy-five years ago, the author's views were much in accord with the more

radical theories of to-day, for he was an inveterate foe of "vitalism," denying that there is any difference between the physiologic and psychologic laws. "Life," he said, "is made up of special chemical and physical phenomena," and he claimed to have made the first step in elucidating these laws, in dicovering the phenomena of endosmose. He was the first to ascertain the condition under which the movement of the sap of plants takes place. The book is written in easy French, and will serve as a convenient exercise to a student studying that language and also interested in biology. HENRY LEFFMANN.

ELEMENTS OF MAP PROJECTION with Applications to Map and Chart Construction. By Charles H. Deetz, Cartographer, and Oscar S. Adams, Geodetic Computer, Special Publication No. 68, U. S. Coast and Geodetic Survey. 163 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1921. Price 50 cents.

This volume is a comprehensive treatise on all the more useful projections presenting them in as simple a form as possible in their general characteristics, mathematical development and actual construction.

Part I covers the subject in general without the employment of any mathematical formulas and serves as a stepping stone to Part II, an arrangement which, it is believed, will best meet the needs of the student and the chart-producing agencies.

In the selection of projections for present-day use in Part II, the authors have limited themselves, with two exceptions, to two classes, *viz.*, projections that are *conformal* and projections that are *equal-area* or *equivalent*. The exceptions are the polyconic gnomenic projections—the former covering a field entirely its own in its general employment for field sheets in any part of the world and in maps of narrow longitudinal extent, the latter in its application and use to navigation.

An interesting feature of the book is given in the frontispiece where a study of a suitable map projection for the United States is presented both by graphical illustration and statistics, including errors of scale, area, and asimuth, in four different projections. It is shown that the projection usually employed for this purpose has a scaling error of as much as 7 per cent. By the use of Albers projection the maximum error of scale can be reduced to 1¼ per cent., and the projection has the additional asset of *equivalence of area*.

Under the subject of "Polyconic Projection" an interesting discussion is given of the merits and defects of the modified polyconic projection as used for the International Map of the World. Another chapter covers the Grid System of Military Mapping as employed in the United States.

The Mercator projection, useful for nautical charts, is presented with detailed and all necessary description, including formulas and tables.

On account of the extensive use of Mercator tables which have not been printed in sufficiently accurate form for forty-eight years, the book should meet a long-felt want. Nearly 15,000 nautical charts are prepared on this system of projection with a probably annual total of over 2,000,000. Under the subject "World Maps" the Mercator projection is again discussed for its usefulness in a continuous conformal mapping of the world, and its impossibilities when extended into the polar regions are explained by the statement that those localities are after all the best places to put the maximum distortion.

For conformal mapping of the world several studies and illustrations are included and among them should be mentioned Guyou's doubly periodic projection of the sphere which, too, has the effect of an interrupted projection.

The problems of world mapping are well outlined in this publication and those projections which have first claim to present-day use are well accounted for at the expense of others which are seldom seen and are more or less geometric trifles.

Due appreciation of the labors of Lambert, Lagrange, and Gauss is shown throughout the book as pioneers in mathematical cartography as well as Gerhard Kramer (Mercator) and the later contributors Germain, Tissot and Herz.

National Advisory Committee for Aeronautics.

Report No. 97, General Theory of the Steady Motion of an Airplane, by George De Bothezat. 70 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921.

The writer points out briefly the history of the method proposed for the study of the steady motion of an airplane, which is different from other methods now used. M. Paul Painlevé has shown how convenient the drag-lift curve was for the study of airplane steady motion. His treatment of this subject can be found in "La Techique Aeronautique," No. 1, January 1, 1910. In the author's book "Etude de la Stabilité I'Aeroplane," Paris, 1911, he has added to the drag-lift curve the curve called the "speed curve" which permits a direct checking of the speed of the airplane under all flying conditions. But the speed curve was plotted in the same quadrant as the drag-lift curve. Later, with the progressive development of aeronautical science, and with the continually increasing knowledge concerning engines and propellers, the author added three other quadrants to the original quadrant, and thus was obtained the steady motion chart which is described in detail in this report.

This chart therefore permits one to read directly for a given airplane its horizontal speed at any altitude, its rate of climb at any altitude, its apparent inclination to the horizon at any moment, its ceiling, its propeller thrust, revolutions, efficiency and power absorbed, that is, the complete set of quantities involved in the subject, and to follow the variations of all quantities both for variable altitude and for variable throttle. The chart also permits one to follow the variation of all of the above quantities in flight as a function of the lift coefficient and of the speed.

The author also discusses in this report the interaction of the airplane and propeller through the slipstream and the question of the properties of the engine-propeller system and its dependence upon the properties of the engine considered alone and of the propeller considered alone will be found treated here in the general manner demanded by actual aeronautical engineering practice. There is also a discussion of the question of a standard atmosphere.

The general theory of the steady motion of an airplane is developed, and after the basic equations have been established and the methods to be used described a general survey of the properties of airplane steady motion is given. A detailed discussion of climbing phenomena will be found and the general formulas established for the rate of climb and time of climb, which quantities under the simplest assumptions appear as hyperbolic functions of the ceiling.

PUBLICATIONS RECEIVED.

A Textbook of Organic Chemistry, by Joseph Scudder Chamberlain, Ph. D 959 pages, 12mo. Philadelphia, P. Blakiston's Son and Company, 1921. Price $4.00 net.

Handbook of Standard Details for Engineers, Draftsmen and Students, by Charles E. Hughes. 312 pages, illustrations, 16mo. New York, D. Appleton and Company, 1921. Price $6.00 net.

Traité de Balistique Extérieure par l'Ingénieur général P. Charbonnier. Tome I, Balistique Extérieure Rationnelle. Les théorémes généraux de la balistique. 637 pages, illustrations, 8vo. Paris, Gaston Doin and Gauthier-Villars et Cie., 1921. Price, in paper, 75 francs.

Rayonnement. Principes Scientifiques de l'éclairage, par A. Blanc. 212 pages, illustrations, 16mo. Paris, Armand Colin, 1921. Price, in paper, 5 francs.

Telegraphie et Telephonie Sans Fils, par C. Gutton. 188 pages, illustrations, 16mo. Paris, Armand Colin, 1921. Price, in paper, 5 francs.

Traité de Dynamique, par Jean d'Alembert. 2 vols., illustrations, 16mo. Paris, Gauthier-Villars, 1921.

A Course of Qualitative Chemical Analysis of Organic Substances with Explanatory Notes, by Olin Freeman Tower, Ph. D. Fourth edition, revised. 89 pages, 8vo. Philadelphia, P. Blakiston's Son and Company, 1921. Price $1.50 net.

The Magnetic Mechanical Analysis of Manganese Steel, by Sir Robert Hadfield and Messrs. S. R. Williams and I. S. Bowen. Reprinted from the Proceedings of the Royal Society, A vol. 98. 6 pages, diagrams, 8vo. London, 1920.

National Advisory Committee for Aeronautics. Technical Notes, No. 46, The Theory of the Ideal Windmill, by Wilhelm Hoff. 15 pages, plates, quarto. No. 56, The Development of the German Army Airplanes During the War, by Wilhelm Hoff. 23 pages, plates, quarto. No. 58, Absolute Coefficients and the Graphical Representation of Aerofoil Characteristics, by Max Munk. 11 pages, plates, quarto. Washington, Committee, 1921.

Dyer's Formulas, For Use in Connection with the 1921 Fall Season Shade Card of the Textile Color Card Association of the United States, Incorporated. 25 pages, narrow 8vo. New York, National Aniline and Color Company.

Atomic Weight of Geranium.—John H. Müller of the University of Pennsylvania has determined the atomic weight of geranium by heating a known mass of potassium fluogermanate in a current of hydrogen chloride, and weighing the residual potassium chloride (*Jour. Am. Chem. Soc.*, 1921, xliii, 1085–1095). Seven determinations gave, as an average, an atomic weight of 72.418 for geranium.

J. S. H.

CURRENT TOPICS.

A Novel Magneto-optical Effect. Elihu Thomson. (*Science*, June 24, 1921.)—In April, 1921, at the River Works plant of the General Electric Company a curious illumination of the space near an electric welder was noticed as the current was turned on and off. Mr. Malcolm Thomson, the son of the author, examined the phenomenon and found that the luminous effect was spread in the magnetic field of a single loop of the transformer, which was carrying about 7000 amperes. Sunlight from high windows was streaming across the space where the effect occurred. This could be best seen when the observer looked across the magnetic field and also the sunbeam into the shadowed region beneath. The magnetic lines of force were roughly perpendicular both to the beam and to the line of vision. To the person thus directing his eyes the luminous effect manifested itself when the current flowed and disappeared when the current ceased. It was visible four feet from the loop and its intensity varied but little up to two feet from the loop.

The author surmised that the effect might be due to fine particles of iron, or of iron compounds floating in the air, derived from the process of welding. Confirmation of this was got when it was noted that airing the room diminished the conspicuousness of the phenomenon while the bringing up of an iron arc to the vicinity of the loop enhanced it. The fumes from the iron were only fairly visible in the sunlight. At the instant the magnetic field was formed they at once became much more luminous only to become duller as soon as the field disappeared. It was further discovered that a strong direct current in the loop was as effective as the previous alternating current. This shows that the effect is not dependent upon the direction of magnetization. It was early found that the light concerned in this luminous effect was polarized. "The very curious fact was discovered by me that the fumes from the iron arc were composite so far as analysis by the polarizing prism was concerned. The bluish-colored smoke arising gave but little effect, but there was with it a yellowish-gray fume, which was highly luminous in one position of viewing by the prism and invisible when the prism was at right angles to that position. This indicates complete polarization when the field is on, for light diffused from the particles in the yellowish-gray fumes. This is an extraordinary effect, for which no evident explanation suggests itself, for the field lines are not straight but wrap themselves around the coil or loop in curved directions; and the effect is apparently complete even with the fumes rising in the space where the lines are strongly curved."

A microscope slide was made to catch a deposit of the fumes. Under a high power this appeared to consist of rounded particles between .0001 and .0002 mm. in diameter resembling a string of beads with intervals between them. The effect may well be due to these forming lines in the magnetic field. G. F. S.

On the Atomic Weights of Chlorine from Certain Minerals.—MLLE. IRENE CURIE. (*Comptes Rendus,* April 25, 1921.) By the road of analysis through the use of positive rays Aston has shown that chlorine is made up of two isotopes whose atomic weights are respectively 35 and 37. The chlorine which has been used in the determination of the current atomic weight of 35.46 must be a mixture of the two isotopes. If chlorine, derived from various ancient minerals of the earth's crust, be examined will it show the same relative proportion of the two constituents? The general process of comparison was this—the chlorine contained in the mineral was converted into a soluble chloride, and was used to precipitate the silver from the nitrate of silver solution. A soluble chloride of ordinary derivation was made to precipitate the silver from a mass of silver nitrate equal to that previously employed. The weight of the two precipitates of silver nitrates were compared. In one case only was there a difference exceeding experimental error. In two instances no such difference was found. "The result in the cases of apatite and sodalite lead to the thought that in general the atomic weight of the chlorine contained in ancient minerals differs scarcely at all from that of normal chlorine derived from sea water. If this result were generalized, one would be led to conclude that there was a very perfect mixture of the two isotopes before the minerals were formed, or that the two isotopes were made from the beginning in sensibly constant proportions."

G. F. S.

Metric System Adopted in Japan. (*Chem. News,* June 17, 1921, page 286.)—The new Weight and Measure Law as passed by the Diet was formally promulgated recently by the Japanese government, thus rendering Japan one of the metric countries. Simultaneously with the promulgation of the new law, Director Kitsukawa, of the Weight and Measure Office, gave out a statement, saying that even when the first weight and measure law was framed in 1893, Japan was desirous of adopting the metric system, but the nation was not ready to accept it, and the old systems were fully adopted. "Several times since, the wholesale reform of the weight and measure systems has been attempted," the official's statement continues, "but it was quite difficult, before the war, to break with the old systems and adopt the new one to which the nation was but little accustomed. When the World War started, however, the necessity of adopting the metric system was keenly felt, and the Government Bill was readily accepted by the Diet." According to the *Yokohama Chamber of Commerce Journal,* within the five years beginning with the date from which the law takes effect, all public works, government offices, schools, and large factories will be made to adopt the new system, while the general public will be given twenty years' grace.

Bureau of Industrial and Scientific Research and of Inventions. R. LEGENDRE. (*La Nature,* May 28, 1921.)—After a year of the war France mobilized her scientists and her laboratories. At the close of hostilities it became necessary to decide whether this well organized and fruitful service should continue. " In view of the approaching economical awakening that follows all wars, in face of the menace of German industrial activity, seeking with unravaged resources to take prompt revenge for a military defeat by winning an industrial victory, many Frenchmen thought that the time had come to realize otherwise than in mere talk the union of the theoretical with the practical man—an alliance so much desired and urged and the theme of so many jeremiads even before the war." Accordingly Parliament decided to maintain the existing organization and to adapt it to the needs of peace. The director, J. L. Breton, obtained the collaboration of all laboratories, both public and private, of the laboratories of universities and of technical institutions, and of the great centres of independent research, such as the Pasteur Institute, and the Eiffel Laboratory. On the other side he put himself in touch with inventors and assisted them to turn into concrete and useful form their often vague and impractical ideas. The Bureau is now housed at Bellevue, just outside Paris, a town known to many art students of the A. E. F. University. Its methods of procedure arouse memories of similar practices in the United States during the war. The proposals of inventors are first brought before a Main Committee which eliminates utopian ideas and those without interest or practical bearing. The promising projects are referred to competent technical committees, who get into touch with the inventor, inform him of the literature relating to his subject, help him in his researches, assist him in making models, guide him to definite embodiment of his conception and in some cases point out practical applications hitherto not thought of. Every week the chairmen of the committees get together and go over the various suggestions under consideration. Since 1919 more than 500 proposals have been submitted. The Bureau is not merely a passive recipient but takes the initiative in asking for help in the solution of problems pressing on France at the present time, such as the better utilization of fuel, the employment of crude oil for motors and for furnaces, the use of the energy of the sun and of the tides, and the study of the chemistry of soils. Another phase of the work is the assisting of scientists who have a valuable idea but lack material, apparatus or other means to conduct experiments until it is embodied in a practical application. There is a growing number of industrial managers who come to the Bureau with their problems for solution.

An interesting list of practical products of the Bureau is given, including Corne's lighter, which gives a flame under water; the airplane of Gastambide and Levavasseur with variable surface, combining rapid flight with safe landing, and the employment of seaweed in place of oats for horses. On still a different side are to be

noted the information furnished for the protection of blast-furnace workers against gas, methods of ferreting out lesions caused by the injection of substances in order to simulate injuries, moving pictures taken for the study of industrial fatigue, data on building material, studies on helicopters and methods of drying wood.

It is much to be hoped that this very useful Bureau will receive support to a much greater extent from the French government as soon as the financial condition of the country will permit it.

G. F. S.

Dr. Edward Bennett Rosa, chief physicist of the Bureau of Standards, died at his work on May 27, 1921. The son of a Methodist minister, he was somewhat older than most students when he was graduated from Wesleyan University, and his powers were so matured that during his first year at Johns Hopkins he undertook the determination of the ratio existing between the two systems of electrical units and carried it to a successful conclusion. While he was at a later time professor of physics at Wesleyan, he contributed largely to the design and satisfactory operation of the food calorimeter.

In 1910 he was appointed physicist in the Bureau of Standards, and nine years later became chief physicist. His researches deal with the determination of the coulomb and with methods of standardization and measurement, but along with this side of his scientific usefulness went a no less valuable ability to organize and to bring to pass. This quality has been of the highest value in the Bureau.

Those who were fortunate enough to know him well will treasure the memory of the high-minded, deeply religious man even more than that of the leader in physical research. G. F. S.

Acid Sulphates.—JAMES KENDALL and ARTHUR W. DAVIDSON, of Columbia University (*Jour. Am. Chem. Soc.*, 1921, xliii, 979–990), find that barium, calcium, and magnesium form acid sulphates in which one molecule of the neutral sulphate is combined with three molecules of sulphuric acid. Mercurous mercury forms an acid sulphate by union of one molecule of the neutral sulphate with one molecule of sulphuric acid. Silver forms two acid sulphates, in which one molecule of the neutral sulphate is combined with one molecule and two molecules, respectively, of sulphuric acid. Acid sulphates of zinc and ferrous iron exist, but their composition has not been determined. Isolable acid sulphates could not be obtained from the neutral sulphates of aluminum, nickel, lead, ferric iron, copper, and mercuric mercury. The acid sulphates of the alkali metals are more stable and more complex than those just enumerated. Arranging the metals in the order of the electromotive series, formation of acid sulphates is found to be dependent upon the position of a given metal with respect to hydrogen. Extensive for-

mation of acid salts is a characteristic of metals which are much above hydrogen like lithium and potassium, or much below hydrogen like silver. As the zero point is approached from either side, the complex compounds decrease in stability, and finally such compounds cannot be isolated. Solubility relationships follow a similar course. The sulphates of the alkali metals and silver sulphate are extremely soluble in sulphuric acid; those of the metals, which are less pronouncedly positive or negative, are much less soluble; those of the metals, which have electrode potentials near to the zero point, are practically insoluble. J. S. H.

Aero-Photographs of Estates (Harrington's *Photographic Journal,* January 1, 1921).—There recently appeared an advertisement of the sale of an estate, in which features of the property are admirably shown by two aerial photographs taken by the Aerophoto Company. According to the *London Times,* this is the first occasion on which photographs taken from the air have been employed for such a purpose, and emphasis is very properly laid upon the advantages which they possess. The aerial method is able to achieve with certainty, and under any topographical conditions, which has been occasionally possible when a distant view-point on ground at a higher level has permitted. But the cases in which an estate is so situated at the bottom of a basin, on the sides of which the telephotographer may erect his camera at any point of the compass, are few and far between, and even under the most favorable of such conditions one can never expect to show the plan and surroundings of a country mansion in so satisfactory a manner as that which is illustrated in the two aerial photographs to which we are referring. One has only to compare these latter with the eight photographs taken on the ground, which are reproduced on the same page of the *Times,* in order to perceive at a glance the superiority of the aerial method. While that superiority is marked particularly by the showing of the relation of the house to the immediate surrounding country, the architectural design of the building receives at least as adequate a representation as it would in a photograph taken from a relatively near standpoint on the level.

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STUDIES IN THE FIELD OF LIGHT RADIATION.*

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THE direct study of the phenomena of light, independently of any hypothesis, leads to the following conclusion: "Light is produced by a periodic phenomenon which is propagated."

Every radiation, however complex it may be, may be decomposed into a certain number, finite or infinite, of such periodic disturbances; each of these is the simple element of every radiation. I propose to give in what follows a review of the researches, carried on since the days of Newton, which have led to the discovery of all possible types of radiation, and have made this subject one of the most immense fields of study that can be met in physics.

Let us recall the essential elements characterizing every propagation of a periodic phenomenon. They are three in number:

1. The *period* is the essential element of every periodic phenomenon, and is independent of the mode of propagation. The number of periods per second, *i.e.*, the *frequency*, can also serve to characterize this element;

2. The *velocity*, on the contrary, characterizes the propagation, independently of any idea of periodicity;

3. From the periodicity in time and the uniform propagation in space results a periodicity in space, characterized by the wave-length, *i.e.*, the distance the disturbance is propagated during one

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period. This quantity is nothing but the space-periodicity; two points, at a distance apart equal to any number whatever of wave-lengths, are the seat of concordant phenomena. These three elements, T, V and λ, are evidently connected by the relation $\lambda = V\ T$. If two of them are known, the third may be deduced.

These three quantities are found in the most diverse phenomena, whenever there are at the same time periodicity and propagation. They are found in the propagation of sound, in the periodic motion of a long cord; simpler still, they are found in the displacement of a material body which moves with a periodic change of shape. We may take as the simplest illustration a man who walks taking equal steps. His body, by itself, has a periodic motion; the wave-length is a double step; in two positions separated by a multiple of this length the body is in the same position.

In the cases cited the three quantities, T, V, λ, may be measured directly; no one of them is so small as to escape our means of observation. The condition is not the same in luminous phenomena. In this case the velocity is enormous, and the wave-length, although measurable, is very small. It follows that the period is extraordinarily small, or, what is the same thing, the frequency is immensely great; this time periodicity is completely beyond our powers of direct observation. Let us state the order of magnitude of these various quantities. In a vacuum the velocity is 300,000 kilometres per second; that is to say, in one second light traverses a distance nearly equal to that from the earth to the moon. For a radiation producing in our eyes the sensation of green, the wave-length is in the neighborhood of half a micron (1 micron = $\frac{1}{1000}$ of a millimetre = $\frac{1}{25000}$ of an inch). The frequency, then, equals the number of half microns contained in 300,000 kilometres. If we again consider the comparison with an animal that is walking, it is necessary to suppose that, taking steps half a micron long, it reaches the moon in one second. We can picture that the motion of its legs would be extraordinarily rapid, and that it would be impossible to see the movements; if we were to see this extraordinary creature passing, it would be impossible to say whether it was running or sliding on its path. Only by examining the tracks of the minute steps in the ground could one learn the mode of advance, and only by comparing the length of the steps with the velocity of advance could one calculate the enormous number of steps made each second.

From these details there results a fact which is most interesting. All the equations of optics contain the time as the fundamental variable; yet optics is the only part of physics in which a chronometer is scarcely ever used. Time itself enters into only one experiment of optics, the determination of the velocity of light. This is a measurement which is rarely repeated, and only then when we believe that we have improved our methods of measurement. We determine often, under the name, "indices of refraction," the ratios of the velocities of light in different media, but this does not require an instrument for measuring time. As for the values of the periods, it is never found necessary to calculate them. For every simple radiation, it is the wave-length that experiments give us; and it is this quantity (taken in a definite medium, *e.g.*, air) that is given in order to specify the radiation.

The ensemble of radiations thus forms a continuous series; each is defined by a value for its wave-length; and we do not have any difficulty in picturing all possible values, from the largest (frequency relatively very small) to the smallest (frequency increasing indefinitely). The range actually explored is nearly infinite.

One region, that of radiations which affect our eyes, was explored as a consequence of Newton's discoveries. The first determination of wave-lengths would naturally follow the discovery of the individuality of simple radiations. On studying the colors of thin plates, Newton himself recognized the periodic constitution of the light, and measured, under the name of "intervals of fits," the half wave-lengths of the various radiations. It is interesting to note that the concept of periodicity was introduced into optics by an advisary of the wave-theory, while the ideas are much less clear with the first defenders of this theory; thus the concept of periodicity was not recognized by Huygens, and the ideas of Euler are quite contrary to the facts of experiment.

The numerical results obtained by Newton remained unused, and even misunderstood, during a century. It was not until the work of Young and Fresnel, at the beginning of the nineteenth century, that the concept of periodicity, attached to each simple radiation, assumed all its precision and importance. It was sufficient to explain all the great variety of phenomena known henceforward under the name of interference phenomena. Each of

these gives a value for the wave-length of the light used; having proved that, for red light, all the phenomena led to the same value for its wave-length, identical with that given by Newton, Fresnel simply doubled Newton's intervals of fits so as to have the wave-lengths of the different colors. An investigation made with greater precision would have been, at this epoch, without meaning: neither the possibility nor the need of accurate measurements was recognized. The essential point, definitely acquired, was this: The wave-lengths of luminous radiations form a continuous progression from the violet to the red, from about 0.4μ to about 0.8μ.

A long series of investigations, extending nearly over a century, contributed an ever-increasing power in the means of separating and analyzing the radiations, a realization more and more perfect of monochromatic radiations, a greater and greater precision in the measurement of wave-lengths. I cannot here give the story of this beautiful series of investigations; it will be sufficient to recall the names of Fraunhofer, of Fizeau, of Foucault, of Kirchhoff and Bunsen, of Angström, of Rowland and of Michelson. From the standpoint of precision measurement, it can be stated that the era of progress is closed. Wave-lengths may be compared with each other with the same precision as that in which the wave-lengths are themselves defined; moreover, they may be compared with the unit of the metric system with an accuracy equal to that with which the metre is itself defined, that is to say, with an uncertainty scarcely exceeding one part in 10,000,000.

In expressing wave-lengths one makes use, naturally, of units derived fom the metric system; but it is necessary to choose a submultiple of the metre small enough for the numbers to be convenient. When great precision is not sought, the familiar unit, the micron, is convenient. For exact figures the usage is established of taking a unit of 10,000 times smaller, called an angström (abbreviation A). We have then

$$1 \text{ angström} = 10^{-4} \text{ micron} = 10^{-8} \text{ centimetre} = 10^{-10} \text{ metre}.$$

The wave-lengths of visible radiations are thus found to lie between 4000 and 8000 angströms. It is found that this unit, selected at a time when one knew nothing accurately about molecules, is of the order of magnitude of molecular dimensions, and that it is suited also for studies of atoms and of X-rays. The

atomistic physicists often, in fact, use it, but keep for it the name which connects it with the metric system, namely "tenth metre."

All this development of methods of measurement was made by means of visible radiations, the study of which is the easiest. At the same time progress was made in the discovery and the exploration of other radiations which the eye does not perceive; methods invented for the visible radiations were applied immediately to these new ones.

The existence of non-visible radiations, the natural extension of the series of luminous ones, was revealed as soon as one wished to study the properties of light other than visual. This led to the use of receiving apparatus other than the eye, less specialized than it. Can there exist a universal receiving instrument, that is to say, one which is sensitive to every radiation, whatever its wave-length is? Certainly yes; such a receiver is supplied by a thermometric apparatus, which absorbs radiation; transforms its energy into heat, and measures the quantity of heat liberated. From a certain point of view, every radiation may be considered as bringing about a transfer of energy from the source of radiation to any point whatever of the surrounding space. If this radiation is destroyed by absorption, its energy is not lost (energy is indestructible); it is transformed into heat, and the number of calories liberated per second serves as a measure of the intensity of the radiation absorbed. All radiations are thermal ones, and to an equal degree if of the same intensity. The expression, "heat radiation," is often used; if it is used to designate *any* radiation, it is a pleonasm; if one wishes to designate by it a definite category of radiations (the infra-red, most often) it implies a false idea; these radiations not having any privilege in this respect. It is found, merely, that certain infra-red radiations are often more intense, and therefore give greater thermal effects than others.

These ideas which are evident now were not always so, although the heat effects of radiation have been known for a long time. Without going back to Archimedes, the experiments with burning mirrors often attracted public curiosity in various countries in the eighteenth century. The systematic exploration of the spectrum from the thermal point of view seems to have been made for the first time by William Herschell, in 1800; the prolongation of the solar spectrum beyond the red at once became evident. The exact meaning and the importance of this

experiment were realized only gradually; it was necessary for attention to be drawn as the result of the work of physicists of the highest rank—among them Ampère—to the complete identity of infra-red and visible radiations; it was not easy to accustom people to this idea that we are completely blind for the majority of radiations. However, although the ideas were not always very clear, methods were gradually perfected, by the use of transparent materials other than glass, and by the invention of more and more sensitive thermometric apparatus, the discovery of which is bound up with all progress in the technic of electric measurements. One must come, however, to a comparatively recent period before measurement of wave-lengths in this region of the spectrum can be found; the first are those of Mouton, in 1879, soon followed by those of Langley. Little by little the region explored was prolonged towards the large wave-lengths; the solar spectrum was followed to 5μ, and with artificial sources Rubens was able to measure wave-lengths running to 300μ, almost 400 times as great as the longest visible waves. Beyond this the intensities of the radiations emitted by our sources of light are probably very weak, and we touch probably the real limit of emission spectra; on this side, the *exploration* of spectra is probably complete. Unfortunately it is not as easy as one could wish, and there remain many properties to be discovered, owing to the lack of suitable means of observation. The thermometer is the "standard" instrument for the measurement of intensities; it alone gives a direct measurement of energy; but as a detecting instrument, even in a perfected form, the thermometer remains greatly inferior to the eye or to the photographic plate with reference to usefulness, sensitiveness and fineness of definition; great progress in these respects is still desirable.

On the side of the shorter wave-lengths, beyond the violet, the discovery of the invisible radiations might also have been made by means of the thermometer; it was not thus made because the intensity of these radiations in terms of energy is ordinarily feeble, and more sensitive detectors could be used immediately. The means universally adopted for the study of ultra-violet radiations consisted in using photographic processes, the development of which was in four steps: Daguerre plates (Daguerre, 1829); wet collodion (Talbot, 1839); bromogelatine (gradual development from 1850–1880); orthochromatism (Vogel, 1873). We are

familiar with the revolution accomplished in the study of luminous phenomena by the constant use of photography; in practice it is used for the study of ultra-violet and visible radiations, and even for the first part of the infra-red—up to more than 9000 A—it is the ultra-violet which has benefitted most by the use of photography.

If one passes progressively towards the short wave-lengths, the study of the ultra-violet begins with a minimum of difficulty. The limit between the violet and the ultra-violet radiations is not a frontier either from a theoretical viewpoint or from a technical one; there is no difference in the nature of the two types of rays; and the methods used for their study are exactly the same. In proportion to the distance one advances towards the shorter wave-lengths the difficulties increase. About the wave-length 3400 A, glass begins to become strongly absorbing and it is soon necessary to give up using it; happily certain crystallized substances, of which quartz is most often used, preserve their transparency and replace glass. About 2900 A the solar spectrum ends, owing to absorption by the ozone in the higher levels of the earth's atmosphere; numerous artificial sources keep a great intensity. Without too much difficulty, one can photograph and measure radiations whose wave-lengths are as small as 1850 A; this is the limit reached by Cornu working from the year 1881 on. Starting from there, the difficulties suddenly become so great that one can ask if it is possible to overcome them. Quartz, in its turn, becomes strongly absorbing, and it is necessary to give up the use of this fine substance; the gelatine of the plates becomes so opaque that the radiation does not penetrate it and no longer acts upon the silver salt; finally, the most serious difficulty of all, the air itself ceases to be transparent and absorbs all the radiations by a very small thickness. Cornu, after making clear the causes of the limitation of the spectrum in his experiments, seems to have given up the attempt to overcome the difficulties which arose.

They were overcome a little later by Schumann in 1890. The three parts of the problem were solved in the following manner: (1) Quartz was replaced by fluorite, whose transparency extends much farther; (2) photographic plates without gelatine were obtained; (3) the apparatus was placed in a vacuum. The spectrum of hydrogen obtained under these conditions showed an enormous extension compared to what had been known; it was limited

solely by the opacity of fluorite, which in its turn ceases to be transparent at $\lambda = 1200$. Moreover in the experiment by Schumann, the wave-lengths were not measured, only estimated, using an extension of the dispersion formula for fluorite.

In order to proceed still further toward the short wave-lengths, in the absence of any known transparent substance, it was necessary to suppress every solid body in the path of the rays; this led to the necessity of rejecting all the ordinary apparatus of optics, both lenses and prisms. There are only two means at our disposal: Reflection by metallic mirrors, and the use of diffraction. This led to the use of the concave grating which had been introduced into optics by Rowland; the use of this apparatus has, at the same time, the advantage of giving directly the lengths of the waves, which the prism does not. With a concave grating in a vacuum, Lyman succeeded in determining the lengths of the waves in the spectra studied by Schumann; then in prolonging these spectra beyond the limit of transparency of fluorite, and finally he reached wave-lengths of 510 A in the spectrum of helium.

A last step in advance has been made recently in the same path by Millikan, using powerful means and a new method to produce the emission. The spectroscopic apparatus is still a concave grating, placed in a high vacuum (pressure 10^{-4} mm. of mercury); the source of light is a high potential spark between metallic electrodes in the same vacuum. The spectra obtained are extremely rich in rays, and extend to 200 angströms.

This is the limit reached to-day in the study of radiations by optical means. It is seen that the study of the ultra-violet has led to an enormous increase in our domain, since on passing from the last visible radiation ($\lambda = 4000$) to the limit reached in the ultra-violet, the frequency increases in the ratio of 1 to 20. Why is the actual limit at $\lambda = 200$? Is it, as at the other end of the spectrum ($\lambda = 3{,}000{,}000$ A), owing to the lack of production of radiation beyond this limit? Is it, in other words, a "production crisis" that stops us? Certainly not; the radiations near the limit are still emitted with great intensity; we are stopped by an accumulation of technical difficulties, and in particular by a "transportation crisis," since the radiations are absorbed by the least trace of matter.

While these beautiful researches were extending the domain of radiations towards the short wave-lengths, a brilliant series of

discoveries in another field revealed to spectroscopists another "promised land." In 1895 the discovery by Röntgen of X-rays had shown that there existed unsuspected radiations. The properties of these seemed to be completely different from those of of optical radiations: Absence of reflexion; propagation in a straight line without refraction or appreciable diffraction; the property of traversing great thicknesses of nearly all bodies, even those which are opaque to all other radiations. The nature of these radiations appeared at first to be absolutely mysterious; it was all the more difficult to prove that there was, in a way, no means of acting on them, and that the ordinary technic of optics was not applicable to them. The absorbing power of various substances was almost the only property that could be expressed by numbers. These feeble means of study were sufficient to prove that X-rays, like luminous ones, were non-homogeneous; and the concept was introduced, almost unconsciously, that they formed also a continuous series of simple radiations each characterized by some peculiarity. The rather vague distinction of soft rays (easily absorbed) and of hard rays (absorbed with difficulty) was introduced into practice; at the same time important studies were made in which each X radiation was characterized by the coefficient of its absorption by a definite substance. As to the nature of these rays, many physicists thought, without being able to give a proof, that the X-rays were light waves having extremely short wave-lengths, that is to say, were a hyper ultra-violet. This hypothesis explained the nearly complete absence of diffraction phenomena, and also the absence of reflection and refraction if the wave-length was of the order of magnitude of molecular dimensions. There seemed to be no hope of measuring the lengths of the waves, on account of the impossibility of ruling sufficiently fine gratings.

Suddenly this chimerical hope was realized by the brilliant discovery of Laue (1912). His bold idea was to take as a grating the regularity offered by nature in a crystal. The early work of crystallographers (Romé de l'Isle, Haüy) had accustomed physicists to consider crystals as having a regular arrangement of particles; about 1850, Bravais had developed completely the mathematical theory of lattice systems in order to explain the shape and the properties of crystals. Laue, familiar with the theory of multiple interference, remarked that such a system should act,

with a radiation having a wave-length comparable with the distance between the particles, like a three dimensional grating. Sending a bundle of X-rays through a crystal, the phenomena expected were immediately realized. A short time later Bragg attacked the problem from a simpler point of view, by studying the phenomena of *reflection* by a crystal, which behaves like a medium made up of layers, analogous to the color photographs of Lippmann, but with the layers pressed together many thousand times.

The enigma of X-rays was from then on cleared up; they form the distant extension of the ultra-violet rays; and the field was thus opened for the spectroscopy of these radiations. It being possible to determine the interval between the lattice planes of a crystal, all the elements were at hand required for the determination of the wave-lengths of the X-rays.

The measurements thus made have given wave-lengths comprised between 10 and 0.05 angström. They are waves of the same order as the dimensions of molecules. The γ-rays emitted by radio-active substances form, beyond any doubt, the natural prolongation of the group of X-rays toward the shorter wave-lengths; the lattice grating of a crystal becomes, in its turn, too large spaced to analyze them. Certain physicists think that the wave-lengths of the γ-rays may be as small as a thousandth of an angström, but this is still hypothetical.

Thus, on descending towards the decreasing wave-lengths, we lose the ultra-violet rays at about 200 angströms, and find the X-rays at about 10 angströms; between the two there is an unexplored region fairly wide. What can exist in this unknown land? Starting from the side of the X-rays and going towards the increasing wave-lengths, one should find radiations more and more easily absorbed; this absorption should then pass through a maximum and gradually decrease. At a certain point (we do not know where), the reflective power of metals should begin to be evident. Refraction, zero for the X-rays and very marked for the ultra-violet rays, should begin to appear in the unknown region; but it will be difficult to note its beginning on account of absorption. All this region will moreover be the most difficult to explore of the entire spectral domain.

Through this difficult "no man's land" a path has just been traced by M. Holweck, working in the laboratory of Mme. Curie. The direct measurement of the wave-lengths has not yet been

made, and will, without doubt, be extremely difficult; but the existence of the radiations intermediate between X-rays and ultra-violet ones has been proved, and some of the properties predicted have been verified. The mode of production adopted is the same as that used for X-rays: The apparatus is a sort of Coolidge tube, made entirely of metal, in which the anode and cathode are separated by the distance of one millimetre. The tube is worked under an exceedingly low potential (between 25 and 1800 volts); the wave-lengths are calculated by the theoretical formula, verified in the case of ordinary X-rays,

$$\lambda = \frac{12,400}{E}$$

in which λ is the wave-length expressed in angströms and E is the potential in volts.

As a detector, M. Holweck makes use of the ionizing properties of the rays, which they share with X-rays and ultra-violet ones. Emerging from the tube where they are produced, the rays enter an ionization chamber containing air at a pressure of 1 mm.; the existence of the radiation is manifested by the electric conductivity of this air, as indicated by an electrometer. It was most difficult to separate the ionization chamber from the tube by a wall which is air-tight and yet transparent for the most absorbable waves; the problem was solved by using a window made of celluloid having a thickness of only ¼ micron ($\frac{1}{100,00}$ of an inch). It was possible to detect a radiation for E = 25 volts, which corresponds to a wave-length 493 angströms; thus joining the known region of ultra-violet radiations. The absorbing power for various radiations has been measured for several gases and for celluloid; it is found that for this last substance the absorption passes through a maximum for $\lambda = 320$ A; the sheet of thickness one-quarter of a micron permits to pass only three per cent. of this radiation.

It can then be said that from the extremity of the X-rays ($\lambda = 0.05$ A) to the extreme infra-red rays ($\lambda = 3,000,000$ A) there is but a single field of radiations; from one end to the other, the wave-lengths vary in the ratio of 1 to 60,000,000. On the side of the X-rays, this vast domain is prolonged by the γ-rays, whose wave-lengths have not yet been measured; on the side of the long wave-lengths it nearly makes connection with the electric waves which differ from optical radiations only with reference to their mode of production. The exploration of the domain of radia-

tions is then very far advanced, and one can with a single glance of the eye, contemplate its entire extent and all its beauty.

Can one say that all discovery in this chapter of physics is now ended? Nothing is farther from my thoughts. If the *exploration* of the land is nearly finished, the realization of its importance has only begun. Knowing the methods suited to produce the various radiations, the methods which enable one to analyze and measure them, a vast field of investigation is open to the physicist: The study of the reciprocal relations between the radiations and matter, which offers the most powerful means for penetrating into the knowledge of matter. Now this study has hardly begun. For no substance can one actually indicate, even approximately, the position of *all* its absorption bands; for no body can one trace completely its absorption and dispersion curves. For no substance can one describe with certainty the entire group of radiations that it can emit, from the X-rays up to the extreme infra-red. The knowledge of fluorescence, a most general phenomenon, is still rudimentary.

If this work is not more advanced, it is first of all because being so vast, it can not be finished except after a very long time; but there is another reason. Through a great part of its field, spectroscopy still is a very difficult science; its methods are those of the explorer who is never sure that he will reach his goal, and not those of the ordinary worker who is sure of his means of production. In the region from $\lambda = 2000$ A to $\lambda = 9000$ A, comprising the visible spectrum, a small portion of the infra-red and the easy part of the ultra-violet, we have methods which are certain and relatively convenient; but beyond this narrow interval, the means for working are truly too laborious and too difficult. Many technical improvements are desirable.

The materials used are not always those which one could wish. With the exception of glass, one is almost entirely bound to natural crystals, that is to say, to chance; the number of deposits is very limited, and physicists are at the mercy of an industrial exploitation very limited and very intermittent. Quartz is found without too much difficulty; but fine crystals of calcite, used in many researches, are found only in Iceland, and now this substance has nearly completely disappeared from the market. Fluorite, which for certain purposes cannot be replaced, is a substance very rare and very expensive, and the most beautiful specimens of it

are very small; the number of good prisms of fluorite existing in the world may be counted probably only as a few dozens. In the infra-red where all substances have absorption bands, one is forced to make use of a certain variety of substances; the physicist does not aways find, among natural specimens, those which he wishes. It would be of great interest if one were to find new artificial materials for use in spectroscopy, either among smelted bodies or among crystals. Some attempts made in America to produce fine artificial crystals have given encouraging results; it is to be hoped that these attempts will be pursued methodically with a large number of substances.

Gratings form another important category of instruments for the analysis of radiations. The results obtained in the construction of these instruments are marvellous; the total number of lines ruled on a single plate, spaced at exactly equal intervals, exceeds 100,000. Unfortunately the commercial state of this industry is not good. The production of gratings is exclusively an American industry; no European instrument maker has ever produced a single grating of any value as an instrument of research. At present the demand for gratings far exceeds the supply; and I could name several European physicists whose researches are stopped because they cannot obtain the gratings essential for their work. If the output of gratings could be increased, it would be of great general usefulness for the progress of physics.

Finally there is a great need of perfecting the apparatus for detecting radiation. The eye, and especially the photographic plate, are the best suited; but their range of sensitiveness is limited. The universal apparatus, the thermometer, in spite of the admirable improvements which it has received, is still difficult to use; its sensitiveness is still insufficient, and its power of definition is less than that of the photographic plate. Other detectors have been successfully tried in recent years: Photo-electric cell, selenium apparatus, method based upon ionization. These detectors can render great service for measurements of intensity, but they are also lacking in power of definition; and moreover, their sensitiveness is strongly selective. A very desirable improvement would be the prolongation in the infra-red of the sensitiveness of the photographic plate; very beautiful results have been obtained already by improving their orthochromatism, which has enabled us to push gradually the limit of sensitiveness of the plates from

about 4800 A to beyond 9000 A; and photography at the beginning of the infra-red is now an easy matter. It is an interesting fact that the development of photography, since Daguerre, rests almost entirely upon the properties of silver salts, discovered by accident. Has it so happened that the first accident gives the best solution? One would be tempted to believe so, after the failure of many other attempts. Unfortunately the theory of photographic actions is so little advanced that systematic researches are very difficult. A happy accident may one day or another open some entirely new way.

We see that, if the rôle of the explorer is reaching its end in the domain of luminous radiations, there remains a considerable task for the technician to accomplish.

Quantitative Precipitation of Gold by Means of the Electric Current. W. D. TREADWELL (*Helvetica Chimica Acta,* 1921, iv, 364–374) states that metallic gold may be deposited quantitatively from its solution as a chloride, by means of the electric current, provided the solution contains ammonium acetate plus either hydrochloric or sulphuric acid. Using this electrolyte and the proper voltage, gold may be separated from copper, palladium, and platinum.

J. S. H.

Use of Catalysts in the Alkylation of Aromatic Amines with Aliphatic Alcohols. ARTHUR J. HILL and JOHN J. DONLEAVY, of Yale University (*Jour. Ind. and Eng. Chem.,* 1921, xiii, 504–509), find that the formation of diethylaniline by the reaction between aniline hydrochloride and ethyl alcohol is promoted to a marked degree by certain catalysts such as a combination of sodium bromide, calcium chloride and cupric chloride, or a combination of sodium bromide and a powdered metallic copper. The combination first mentioned also acts as a catalyst in the formation of the tertiary bases from the three isomeric toluidines (methyl, amino benzenes) by their reaction with either ethyl or normal butyl alcohol. The primary base and the alcohol are mixed so that ten molecules of alcohol are present for each molecule of base; the mixture is heated with the catalyst in an autoclave. Orthotoluidine is the least active of the four primary bases—aniline, orthotoluidine, metatoluidine, and paratoluidine. Normal butyl alcohol is less active than ethyl alcohol; however, the actual *increase* in yield of tertiary base is greater with normal butyl alcohol than with ethyl alcohol.

J. S. H.

ELECTRIC TRACTION—A REVIEW.*

By FRANK J. SPRAGUE.

Member of the Institute.

A RECENT announcement states that in the United States alone electric railways cover a trackage of 44,000 miles and represent a capital investment of approximately $5,000,000,000, while 300,000 men are employed and over 14,000,000,000 passengers are carried annually—ten times as many as are carried by the steam railroads of the country.

In addition, there is the like class of roads in foreign countries, and thousands of miles of trunk lines here and abroad which are electrically operated or for which electrical equipment is planned. This is a brief epitomé of one of the most astounding of industrial growths, the product of but a third of a century of effort.

In accepting the invitation to present a paper reviewing this great development I cannot but feel something of that embarrassment which must unavoidably attend the presentation of facts which, if stated correctly from a historical standpoint, must include something of one's personal contributions, especially as one must lack that true perspective for which time, distance and the impersonality of an historian are essential. But, to quote a distinguished predecessor, reminiscence is one of the privileges of advancing years and an accumulation of experience, and is sometimes permitted by a kindly audience.

The history of the electric railway may be considered as covering various periods—such as, the inception of basic principles, the early crude experiments, the invention and evolution of the dynamo-electric machine, the discovery of the principle of self-excitation and the reversibility of function, the scattered attempts at commercial operation, the advent of the modern trolley, the succeeding technical and commercial developments, trunk-line operation and future possibilities. As to these I shall draw quite freely upon my previous papers on the same general subject.

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* Presented at the Stated Meeting of the Institute held Wednesday, May 18, 1921.

DISCOVERIES OF FARADAY AND HENRY.

Whatever moderns may have done, two names stand out in the early dawn of the electric art, undimmed by the glory of any subsequent achievements. On Christmas morn, just a hundred years ago, Michael Faraday, "late bookkeeper's apprentice, and now turned philosopher," announced the all-important discovery that it was possible to produce mechanical motion through the agency of the electric current and magnetic attraction, and ten years later Joseph Henry, then a Professor of Natural Philosophy in the Albany Academy, who had antedated Faraday in the discovery of electro-magnetic induction between unmoved conductors, announced in a letter to Professor Silliman, of New Haven, another advance, as follows: "I have lately succeeded in producing motion by a little machine which I believe has never before been applied in mechanics, by magnetic attraction and repulsion."

But Henry, coolly analyzing the limitations of the electro-magnetic motor, which, however it might be improved, was still dependent upon the burning of zinc in a primary battery, and clearly recognizing the economic fallacy of any attempt to substitute it for coal as a source of energy, avoided committing himself to impracticable attempts for its introduction into the mechanical world.

THOMAS DAVENPORT, THE PIONEER.

It, therefore, fell to one Thomas Davenport, a blacksmith of Brandon, Vermont, of whom it has been said that his was a mind which could not be confined to any shop less than the canopy of Heaven, to throw himself heart and soul into the attempt to create an industrial revolution by electricity—a project that, at the time, was certain to prove illusory; and to this same man, in all justice, must be given the credit, in this country at least, for the first crude suggestion of an electric railway—the operation of a moving vehicle by electric power supplied from a stationary source.

From about 1833, when Davenport began his electrical career, until his early death in 1851, his life was the typical one of many inventors who have blazed the path for others, the active strivings of a fertile mind urged to constant endeavors and dreaming great dreams, finally beaten to the wall, partly because of the lack of financial assistance but more because he lacked the essential of commercial success, a suitable economic source of electric power.

By 1834 he had built his first crude motor; in the next year he devised the commutator; and in 1836–37 he illustrated on a miniature circular track, two feet in diameter, the principle of an electric railway using current from a central source, with return through the rails.

On February 25, 1837, Davenport was granted the first and broadest patent in America on this general subject, the character of which is indicated by the following claim:

> The discovery here claimed and desired to be secured by Letters Patent consists in applying magnetic and electro-magnetic power as a principle for machinery in the manner above described, or in any other substantially the same in principle.

This wording may fairly be declared to cover the whole field of the utilization of electric power.

I have only touched upon Davenport's activities, the number of which are amazing, but refer to his work to emphasize not only its creative originality and importance, but the undoubted fact that had he had the advantages of the developments which followed in the succeeding years in the evolution of the dynamo, the machine for converting mechanical energy into electricity, and the converse, many of the advances now credited to other inventors would undoubtedly have been his.

OTHER EARLY WORKERS.

A close rival of Davenport was the Russian engineer, Jacobi, who also in 1834 had produced an electric motor, and three years later actually propelled a boat on the river Neva with energy from primary batteries. This decade seems to have been prolific not alone in attempts to apply electric motors to industrial purposes but in a belief in its ultimate universality of adoption. One of the most notable attempts made was that of a Scotch engineer, Robert Davidson, who in 1838 began the construction of an electric locomotive which had a test on the Edinboro-Glasgow Railway; and the thought of many workers was well voiced in the remarkable prediction by Lieutenant LeCount of the British Navy, who in a "Treatise on Railways" published by Black, of Edinburgh, in 1839, said:

> We have no hesitation in saying that electro-magnetism will at no distant day compete with steam as a motive power, and successfully.

The use of rails for carrying the electric current is said to have

been indicated in an English patent issued to Henry Pincus in 1840, and a like use in an American patent issued to Lilley and Colton in 1847. Whatever the fact, it is well established that in the latter year, Prof. Moses G. Farmer, who was one of the ablest of early American scientists, operated an experimental car, carrying two passengers, at Dover, New Hampshire, which was supplied by battery current: Three years later Professor Page, of the Smithsonian Institution, with Congressional aid, constructed a number of motors. With one of these, on April 29, 1851, and with current supplied from a battery of one hundred Grove cells carried on a small car, he operated the latter on a road between Washington and Bladenburg, where it got up to a speed of nineteen miles an hour, with resultant destruction of the batteries and an end of the experiment.

In this same year an instrument maker of Boston, Thomas Hall, made a small motor which was operated by current conveyed to the rails from a primary battery. Nine years later he exhibited a model called the "Volta" at the Mechanics Fair in Boston. Some years before this patents issued to inventors abroad had indicated the possibility of taking current from a suspended conductor.

EVOLUTION OF THE DYNAMO.

These various experiments were, of course, doomed to commercial failure, not alone because the motors were of a crude construction, based upon the attraction of keepers or solenoids, but because the source of power was in all cases a primary battery. They were, however, indicative of what would come later when the evolution of the modern dynamo should take place.

Beginning with improvements by Wheatstone and Cook in 1845, and by Hjorth in 1854, there appeared in 1853 an inventor whose name is, unhappily, now not even known, who is reported to have clearly set forth the vital idea of self-excitation of the field magnets.

The modern dynamo-electric machine dates from the epoch-making invention of the continuous current dynamo by Pacinotti in 1861, which was followed by the announcement of the principle of self-excitation, independently and practically simultaneously, by the Englishmen, Wheatstone, Varley and Ladd, the German, Siemens, and the American, Farmer, in 1866–67.

Three years later a Frenchman, Gramme, combined the two vital features in a single machine, and to him is fairly due the credit of producing the first practical commercial machine for continuous current operation, whether used as a dynamo or motor.

The ring form of armature, invented by Pacinotti and improved by Gramme, ultimately gave way to the drum form of winding proposed by Von Hefner Alteneck of the Siemens firm of Berlin, and also independently by the late Prof. Henry Rowland of the Johns Hopkins University.

REVERSIBILITY OF FUNCTION.

Some time, apparently, relapsed after the development of the self-exciting machine before the remarkable characteristic of the reversibility of function was discovered, with the necessary corollary, the electric transmission of energy by the use of two similar machines connected in the same circuit, one driven by power and generating electricity, and the other receiving electricity and developing mechanical power.

It is claimed that this vitally important fact was discovered by Pacinotti in 1867, but it is certain that for the time being no use of it was made. In 1873, however, Messrs. Gramme and Fontaine demonstrated it at the Vienna Exhibition, where a number of Gramme machines were in use. This discovery is said to have been due to the mistake of a workman who coupled a machine to a live circuit and was astonished to see it begin to rotate. This is quite likely, as the same thing has happened in recent years. Gramme instantly saw the significance of this unexpected occurrence, concerning which the great Maxwell expressed the opinion that it was the most important discovery of modern times.

In the nearly quarter of a century ending in 1875, during which period the modern dynamo and motor had been created, there appeared to be a complete cessation of electric railway experiments. It was not until the latter year that George Greene, a mechanic of Kalamazoo, Michigan, is reported to have built a small motor which was supplied from a battery through an overhead line, with track return, and three years later constructed another larger model. Lacking appreciation of the necessity of using a dynamo for a generator of electricity instead of a battery, or possibly being

without means to get one, his work came to naught. Greene applied for a patent in 1879, and was finally allowed some very broad claims.

FIRST SIEMENS' WORK.

Among the European concerns engaged in buiding dynamos for electric lighting and other purposes, that of Siemens was the most prominent, and naturally the transmission of power soon commanded its attention, with the result that in 1879 this firm showed at the Berlin Exhibition a small car, operating on a track about a third of a mile long, which used a dynamo-electric motor and took current from a third rail, with track return, supplied by a stationary dynamo. On this locomotive the motor was carried longitudinally, the revolutions of the armature being transmitted through spur and beveled gears to a central shaft, from which connection was made to the wheels. Three small cars carrying about twenty people were pulled by it at a speed of eight miles an hour.

In the next year Egger exhibited a model in which the current was supplied through the running rails, and Messrs. Bontemps and Desprez, of Paris, proposed a scheme for the use of miniature electric locomotives in place of the pneumatic transmission of dispatches. This is the same Desprez who actively conducted some of the earliest important experiments in the transmission of power over long distances with direct current at high potentials.

ADVENT OF FIELD AND EDISON.

While these developments were going on abroad two American inventors, the late Stephen D. Field and Thomas A. Edison, began electric railway experiments, but, subject to the claims made for Greene, the credit of the first serious attempt in the United States at this period must be awarded to Field, who, while living in San Francisco in 1877, is reported to have conceived the idea that electric power might be substituted for the cable then used to propel street cars in that city. To carry out some proposed experiments, the first of which was to operate an elevator, he ordered a dynamo machine from Europe. This being lost he ordered a second one. In 1879, his resources being exhausted, he returned to New York and laid his plans for the electric operation of cars with current supplied through a conductor carried in

a slotted conduit before the late Franklin Leonard Pope. In this year he filed a caveat, and followed it by a regular patent application in the next year. This disclosed plans for an electric railway designed to use current from a stationary dynamo, transmitted through a third rail or an insulated conductor enclosed in and protected by a conduit, the traffic rails, divided into sections, forming the return circuit.

Mr. Edison, at this time, was within reach of great electric possibilities, although actually missing them, for in the face of much adverse criticism he had developed, in connection with his electric-lighting system, a low, internal, resistance dynamo with high-resistance shunt field and many of the features of the multiple-arc system of distributon, analogous to that used in gas and water supply.

In 1880 he built a small road at his laboratory at Menlo Park, on which he ran a single locomotive equipped with a lighting dynamo used as a motor. The power was transmitted to the car axle by a belt and the two rails were used as conductors, one set of wheels being insulated. In this year Siemens, Field and Edison became involved in a patent interference. Siemens being ruled out by office limitations as to evidence relating to work abroad, the immediate issue narrowed down to Field and Edison and was decided in favor of the former, to whom was issued a patent covering "the combination of an electric motor operated by means of current from a stationary source of electricity conducted through the rails," a claim manifestly absurd in view of the previous art and void on the ground that the mere substitution of a dynamo in the place of a battery did not constitute invention.

In general, however, because of the facts of equivalency, and also on account of the records of early experimental work, the claims obtained in the patents of this period were distinguished by their paucity and limitations.

FIRST COMMERCIAL ELECTRIC RAILWAY.

The demonstration by Messrs. Siemens and Halske in Berlin in 1879 was followed by other exhibitions by them at Brussels, Düsseldorf and Frankfort, and then they established a short one-car line a mile and a half long at Lichterfelde, near Berlin. This small road was opened for traffic in May, 1881, and may be considered the first commercial electric road on which fares were

collected. The motor was carried on a frame beneath the car body between the axles, the power being transmitted by steel cables from the armature to drums on the axles. The car had a capacity of twenty-six passengers and could make a maximum speed of about thirty miles per hour. The electrical pressure was low, only about 100 volts, and the two rails were used as conductors. This line continued in actual service for a number of years, the method of current supply, however, being later replaced by two conductors carried on tops of poles, upon which ran a small carriage connected with the car by the flexible cable.

This equipment was followed by one at the Paris Exhibition, where overhead distribution was used for the first time; the conductors in this case consisting of two tubes slotted on the under side and supported by wooden insulators, which tubes contained skids held in contact by an under-running wheel pressed up by springs carried on a frame-work supported by the conductors. Connection with the car was made by flexible conductors, and the power from the motor, which was carried between the axles, was transmitted by a flexible chain.

About this time Field constructed and put into operation an electric locomotive on a track in Massachusetts, but this experiment was soon abandoned.

SERIES-PARALLEL CONTROL.

Up to 1881 all proposals to use motors were based upon their individual and separate control, but Dr. John Hopkinson, an English scientist of exceptional mathematical and scientific knowledge, in a patent for the application of motors to hoists, proposed both for them and for tramways the grouping of two motors in series-parallel arrangement, by which method either two motors, or one motor with two armature circuits, could be run at half or full speed by providing a switch so that the current from a source of constant potential could be sent through the two circuits in series or parallel.

In the same year, and quite independently, I contructed a small dynamo at the Torpedo Station, Newport, which had two armature circuits and a switch by means of which like series-parallel combinations could be made, and tests of the machine under these conditions were conducted, first as a dynamo and later as a motor. The direct change-over from one combination

to the other, however, with high electrical pressures or large currents, would be too abrupt and destructive of the controlling switch, and so this practice did not come into commercial use until some time later, when there was combined with the simple series-parallel control a variation of current strength by a resistance in the circuit of the motor, either by varying the arrangement of section of field coils or the amount of external resistance, thus making the change-over easier and giving additional speed increments.

The two functions being progressively effected by Condict by the movement of a single handle, his controller as modified by the addition of the magnetic blowout by Thompson and Potter became a practical feature in everyday operation, and for a long time the validity of patent covering this combustion was upheld. A final adjudication, on the discovery of an Austrian patent issued to Reckenzaun, who had conducted a number of experiments with storage-battery cars, was probably avoided by a combination of the contending interests.

FURTHER ACTIVITIES.

The year 1882 was marked by an increase in electric railway activities. In Europe, the Siemens firm constructed an experimental road near Meran in the Tyrol to demonstrate the possibilities of electric traction for the St. Gotthard Tunnel, and small lines at Frankfort and Molding, followed by a proposal for a combined elevated and underground railroad for Vienna.

In the fall of that year Doctor Finney, of Pittsburgh, devised a system for operating electrically propelled omnibuses with current taken from overhead wires carrying a small trolley connected to the vehicle with a flexible cable. About the same time in England, Professors Ayrton and Perry read a paper on Automatic Railways before the Royal Institution, and Dr. Fleeming Jenkin, the distinguished Scotch scientist, proposed a telepherage system, or automatic overhead railway for carrying merchandise, plans for which were developed by them in concert.

In the same year, Mr. Edison, at the instance of the late Mr. Henry Villard, undertook further experiments at Menlo Park, but save in extent there was little of novelty shown. Both Field and Edison took out some additional patents, one of the latter's being for the control of motors on different cars by a single main controller on a pilot locomotive, a plan never put in

use. Although Field later undertook some isolated experiments, and Edison, at a much later date, essayed an unfortunate attempt to use rail supply at very low potential differences as a substitute for the trolley, both inventors soon ceased to become active factors in the development of the art.

THE MODERN TROLLEY.

Opportunity is often responsible for inventions, and it was largely so for my entry into the electric railway field. As a cadet at the United States Naval Academy in 1874–78 I had become intensely interested in various electrical inventions, and in 1879 and 1881 I had actively begun electrical experiments, the intervening year being spent on a cruise around the world. While on duty on the training ship *Minnesota* in the latter year I made an attempt to introduce the incandescent electric light into the Naval service, current to be supplied from an Edison dynamo driven by a single-cylinder, fly-wheel pump which I intended to divert from its normal duty. But not effecting the loan of a machine this ambition was for the time not realized.

The principal activities of this period concerned the electric lighting field, and were marked by sharp recriminations between the advocates of series arc lights operated wth a constant current at a high pressure and the multiple-arc distribution of high-resistance incandescent lamps at a constant pressure. The application of electricity to motive power seemed to have been largely lost sight of, and the various companies which were formed manifested their limitations by their names, being generally known as "illuminating" or "lighting" companies.

My ambitions being aroused by the opening of the Paris Electrical Exhibition in 1880–81, I terminated my experiments at the Torpedo Station and applied for orders to Paris, failing which I procured an assignment to the *Lancaster*, sailing for the Mediterranean, with leave on arrival, and subsequent orders to the Electrical Exhibition held in 1882 at Syndenham, England. As secretary of a jury I had charge of the testing of dynamos and gas engines. To the best of my recollection there were no stationary electric motors exhibited, but there were many lighting exhibits, the principal one being Edison's, and of course there were no electric railways. While riding upon the underground road I conceived an idea of electric propulsion based upon the use of the

tracks as one conductor, and for the other a system of rigid overhead rails, all in one plane, following the centre line of all tracks and switches, contact with the same to be made by an upward-pressing wheel or cylinder carried by the car over the centre of the truck and supported by springs with lateral movement so as to accommodate the motion of the car upon its springs. This plan followed an earlier suggestion to use a conductor carried between the rails, discarded because of the great complexity of switches which I noted at one of the principal stations.

Resigning from the Naval service, with a year's leave, I returned to the United States in the spring of 1883 to become an assistant of Mr. Edison in connection with his electric light station, and while engaged in this duty I developed a mathematical means for determining and improving the system of central station distribution. I found time, also, to conduct experiments with electric motors, and as a result of my awakened ambition in this field I had a clash with my employer within a year, and formed the Sprague Electric Railway and Motor Company, which was destined to play a leading part in the advancement of the art.

Meanwhile the Edison and Field interests had combined in the Electric Railway Company of the United States, its first move being the exhibition of a small locomotive called the "Judge," which run around the gallery of a building at the Chicago Railway Exhibition. A Weston dynamo was used for the motor, geared to a jackshaft from which power was transmitted to the wheels by belts. The current was supplied from a centre rail, with track return, a lever operated clutches on the driving shaft, and the speed was varied by resistances in the circuit. For reversing the motor two sets of brushes were used, only one pair of which could be thrown in circuit at a time by a lever and disc geared to the brush-holding arms.

VAN DEPOELE'S ACTIVITIES.

Early in this year a Belgian woodworker, Charles J. Van Depoele, who was interested in electrical work, attacked the railway problem in energetic fashion, and being a tireless worker and prolific inventor, left a permanent impress upon it. His first experiments were conducted in or near his works in Chicago, in the winter of 1882–83, where a car was operated by an arc-light dynamo used as a motor, the current being taken from a wire laid

in a trough; and in the autumn the car was shown at the Chicago Industrial Exhibition. This venture was followed by considerable work to which reference will be made later.

About this time Van Depoele is reported to have tried an experiment in which he used an overhead wire with an under-running contact wheel, and this formed the basis of an interference between us, involving the issue of the under-running trolley. Neither of us had applied for patents until about 1886, and while each had made the invention quite independently, it is a moot question if my conception while abroad was not the earlier and more complete. In the interference proceedings, however, despite the fact that I was a Naval officer and had been abroad on duty, the Patent Office ruled that my testimony as to the conception of invention could only be accepted as of the date of my return to the United States in May, 1883. On the basis of this ruling concession of issue of the patent was yielded to Van Depoele, but on account of the closeness of the dates of conception, and possibly because of doubt as to the legality of the Patent Office action, this was on condition that the Sprague company should have free license to use the under-running trolley, while certain special features covering the working conductors and feeders were not reciprocally permitted.

LEO DAFT'S EXPERIMENTS.

Among the active American workers of this period was Leo Daft, who after engaging in the development of motors for stationary work had applied himself to the electric railway problem, making his first experiments at his company's works in Greenville, New Jersey, in 1883. These were resumed in November of that year on the Saratoga and Mt. McGregor Railway, where a locomotive called the "Ampère" pulled a full-sized car. The motor was mounted on a truck and connected by belts to a jack-shaft, from which other belts led to pulleys on the driving axles. The current was supplied from a central rail, with the running rails for return, and at comparatively low potential, while variation of speed was obtained by modifications of field windings.

Meanwhile, commercial work had begun in Great Britain, the first installation being the Portrush Electric Railway to the Giant's Causeway in Ireland, installed in 1883 by Siemens Brothers of London under the direction of Dr. John Hopkinson. The power

was generated by a water turbine, and the current transmitted by a third rail carried on posts alongside the track, with track return, the pressure used being about 250 volts. In the same year there was installed a short road at Brighton, using the running rails, and also experiments conducted with storage batteries at Kew Bridge, London.

The year 1885 showed at least equal activities. Van Depoele operated a train pulled by a dummy at the Toronto Exhibition, taking the current from a conduit below the car; and Daft installed small exhibition roads at the Mechanics' Fair, Boston, the Point of Pines and Coney Island. In August Messrs. Bentley and Knight, who had conducted some experiments in the yards of the Brush Electric Company at Cleveland in the previous autumn, installed a conduit system on the tracks of the East Cleveland Railway Company. This equipment covered a section of the road two miles long, and the conduits were of wood laid between the tracks. Two cars were employed, each of which was equipped with a motor carried under the car and transmitting power to the axle by wire cables. The current was supplied from a Brush constant-current, arc-light dynamo. The equipment operated at intervals during the winter and was then abandoned.

In this year, also, Dr. Wellington Adams, of St. Louis, proposed a radical departure in motor mounting. According to this the armature was carried directly on the axles and the field magnets by a frame rigidly secured to the axle-boxes, this frame also carrying an intermediate gear which formed the connection between the armature pinion and the axle gear. In operation the armature and axle revolved in opposite direction. The scheme was found impracticable and was not introduced commercially.

THE KANSAS CITY ROAD.

In 1884–85 another inventor, John C. Henry, installed and operated in Kansas City a railway supplied by two overhead conductors, on each of which travelled a small trolley connected to the car by a flexible cable. The motor was mounted on a frame carried on the car axle, to which the power was transmitted through a clutch, and a nest of change-gears giving five speeds, very much after the fashion of present-day automobile practice. Subsequently equipping a portion of another road, he conducted a number of experiments in some of which the rails were used as a

return. Various collectors were devised, and one is said to have been carried on the car, but the final selection was a trolley with four wheels disposed in a horizontal plane, carried by and gripping the sides of the trolley wire, and pulled along by a flexible cable connecting it to the car. This feature, using one overhead wire and the rail return, was used on a small road installed by Henry at San Diego, California, two years later.

In the early part of 1885 Prof. Sidney Short, of Denver, began a series of experiments on a short piece of track, followed by the construction, in connection with J. W. Nesmith, of a section of road for conduit operation. The series system was used, a constant current being sent through all the motors on the line in series, by automatically sectionalizing the conductors, the total potential varying according to the number and duty of the motors. Speed and direction of movement were varied by shifting the commutator brushes or diverting a part of the current around the motor. The experiments were continued into the following year and were repeated at Columbus, but failed because of the principle involved. Later, adopting multiple distribution and operation, where each motor is independently supplied from a source of constant pressure, Short attempted the use of gearless motors, but soon reverted to the geared type.

FIRST U. S. COMMERCIAL ROAD.

Daft began work on the Hampden Branch of the Baltimore Union Passenger Railway in August of this year, at first with two motors which pulled regular street cars, and doubled his equipment the following year. Current was taken from a centre rail, with track return, except at crossings, where an overhead conductor was installed, the connection to which was made by a transversely hinged arm carried on the car and pressed upward by a spring. Power was transmitted by a pinion connected with an internal gear on one of the axles.

I believe that this was the first regularly operated electric road in the country, and the conditions of the contract required a year's satisfactory operation before payment. It is said that a certain scientist remarked that any one who would undertake such contract was either a fool or a knave, but this was not the only instance in which those who were strong in the faith were willing to take great risks. That this opportunity came to Daft was due

to the progressive instincts and determination of Thomas C. Robbins, an earnest believer in the possibilities of electric traction, whose efforts met with much of indifference and opposition on the part of the owners of the road.

Encouraged by his success in Batimore, Daft soon undertook a more ambitious experiment, the equipment of a two-mile section on the Ninth Avenue Elevated Railroad, New York, where in the summer of 1885 he operated a locomotive called the "Benjamin Franklin," which, pulling a train of cars, made several trips. The motor was mounted on a platform and pivoted at one end, power being communicated to the driving axle through grooved friction gears held in close contact by the weight of the machine reinforced by an adjusting screw. The experiments were soon suspended, and not resumed until three years later, when for several weeks a rebuilt and improved "Benjamin Franklin" was frequently run between the steam trains on the section between Fourteenth and Fiftieth Streets. A speed as high as twenty-five miles per hour was sometimes obtained, and on one test an eight-car train was pulled up the maximum grade of nearly two per cent. at a seven-mile gait. The adoption of a low potential, to which Daft seemed to have then committed himself, militated against higher speeds.

In the summer of 1885 Van Depoele resumed the operation of the train at the Toronto Exhibition, but on this occasion he used an overhead wire carried on brackets, with a weighted arm pressing a contact wheel up against it. His first commercial installation was made in the autumn at South Bend, Indiana, where five small cars were operated, followed by one at Minneapolis, where an electric car took the place of a steam locomotive. In the following year he installed small roads at Windsor, Canada; Appleton, Wisconsin; Ft. Huron, Michigan; Scranton, Pennsylvania; and Montgomery, Alabama, using on the last a non-reversible under-running trolley carried on the forward end of the car, which was run around a loop for return movement, but on some other roads a travelling trolley carried on the ovehead wire and connected to the car by a flexible cable.

Abroad little was being done. Mr. Anthony Reckenzaun, an advocate of storage battery operation, had conducted some tests in 1883 with an electric launch, and then operated cars in 1884–85 at Millwall and Battersea, England, following with a similar demonstration in Berlin at the end of the latter year. His car

body was mounted on bogie trucks, each of which carried a motor connected by worm gearing to one of its axles. Two sets of brushes were used for reversal, and the speed was varied by grouping the motor armature and field circuits, sometimes also by the use of a starting resistance.

A short road was installed at Bessbrook-Newry under the direction of the Messrs. Hopkinson in 1885, and also one at Ryde in 1886, in which year also Holroyd Smith installed the Blackpool road. In this a conduit system was used with a complete metallic circuit. The motor was carried under the car between the axles and connected by chain gearing. Fixed brushes with end contact were used for both directions in running.

SPRAGUE EXPERIMENTS.

When I separated from Mr. Edison in 1884 and formed my own company it was at considerable personal risk. The company was only a paper one, with a nominal $100,000 capital, all issued to me for inventions and patents, and for which I was to bear the cost of all experimental expenses and perform sundry services for a modest salary which I was to pay to myself. A few shares having been sold and the proceeds soon used for personal expenses, I made a verbal contract with Mr. E. H. Johnson, then president of one of the Edison Companies, by means of which he was to advance certain moneys for a specified interest in the company. One small room sufficed for our business requirements, and the stationary motor development was carried on in the shops of Bergman and Company, New York. But in the fall of the year we had made progress enough to be able to send to the Philadelphia Electrical Exposition a number of motors, among others a new constant-speed non-sparking type, which was the forerunner of a rapidly growing business, accentuated by the endorsement in 1885 by the parent Edison Company for its use by their licensees.

ELEVATED RAILROAD EXPERIMENTS.

My mind, however, soon reverted to the railway problem, and having conceived in 1885 a novel scheme of operation for the Manhattan system, this embracing the now universally used "wheelbarrow" method of motor suspension, I elaborated it to some extent in a paper read before the Society of Arts in Boston in December, 1885. In addition to the axle mounting of the

motors, which were shunt wound, resistances were provided in both the armature and field circuits for variation of speed, return of current to the line and for electric braking.

About this time the Edison-Field interests had installed a battery of small dynamos in the old Durant Sugar Refinery on East Twenty-fourth Street, New York, and Field had made a short trial of a locomotive controlled by a water-rheostat on the Thirty-fourth Street Branch of the Elevated, where a third rail had been laid between the tracks. I had already begun the construction of motors to demonstrate the plans described at the Society of Arts, and the Edison-Field activities having come to a halt arrangements were made by Mr. Johnson for the prosecution of my experiments in connection with the same generating equipment.

The first tests were carried on with two motors mounted on an elevated railway truck under a flat-bottom car, on a track about 200 feet long between the walls of the refinery. Among those who came to see these experiments was the late Jay Gould, then one of the principal owners of the Manhattan Elevated, and it is likely that overconfidence on my part was one of the causes of his subsequent lack of interest in electric developments. Mr. Gould was a man of small stature, and during the operation of the car was standing near the controller and an open safety fuse. On account of the short space for operation the controller which governed the motors for both running and braking was handled quite abruptly, with the result that the fuse blew, with a startling flash, followed by Mr. Gould's attempt to jump off the car.

The experiments were later transferred to the Thirty-fourth Street Branch, and in May of 1886 were witnessed there by a large number of officials connected with the elevated and other enterprises, but although the work continued until December I believe no stockholder or director of the Manhattan road apparently took any further interest in the outcome. But the machines used were the parent models of the modern railway motor. They were centered through their brackets, wheelbarrow fashion, on the driving axles and suspended at the free ends by springs from the transoms. They were single geared, had one set of brushes, were without weather protection, and were used not only for propelling the car but for regenerative braking. During the the latter part of the experiments a second pair of motors was added, with

an interpole winding to maintain fixed non-sparking positions for the brushes. Soon afterwards one of these motors was put into service at the East Boston Sugar Refinery, taking current from a trolley carried on an overhead wire, and was later rescued and the winding restored to illustrate the interpole winding which later has become so important. Two others later operated the first electric snow-sweeper and ice-cutter on the Allston division of the West End Railway in Boston in 1888.

Like many other inventors I was apparently ahead of the times, and, changing my plans for the time, on the suggestion of Mr. J. H. Vail I soon began the equipment of a locomotive car, to be equipped with four seventy-five horsepower motors, each with two armatures geared to the axles and with the magnetic fields in tandem as on the present New York Central locomotives. This is still used for experimental purposes in Schenectady.

TURNS TO TROLLEY PROBLEMS.

The Elevated field offering little of immediate promise, I soon turned my attention to the trolley problem.

Reviewing the conditions at this time, eight years after the Berlin Exhibition by Siemens, it appears that, including every kind of equipment, there had been made only about nine installations in Europe and ten in the United States, with an aggregate of about sixty miles of track and less than a hundred motors and motor cars, characterized by the utmost diversity of practice. There were high and low pressures, series and multiple circuits, traffic-rail conductors and conduits, third-rail return, slotted-overhead tubes, single- and double-overhead wires with single- and double-travellers on them, and upward-pressing arms carried on the cars. The motors were of varied construction and control, generally using two sets of brushes for reversal of movement. One motor to a car usually constituted an equipment, being carried on a dummy or on the front platform, and were connected to one axle by a belt or chain drive. The cars were mostly single ended and controlled from one point. The art was in a chaotic state, and commercial success on a large scale, involving radical departures in practice, was needed to focus the advantages of electric traction, even then thrusting themselves into prominence.

Supplementing small additional roads by Van Depoele at St. Catharine's, Ontario; Lima, Ohio; Binghamton, New York; and

Jamaica, Long Island; and by Daft at Asbury Park, New Jersey; and Los Angeles, California, such an opportunity came in the spring of 1887—and, by good fortune, to my company—in the contracts for the Union Passenger Railways of St. Joseph, Missouri; and Richmond, Virginia; and about the same time one of somewhat different character to the Bentley-Knight Company, on the Observatory Hill Passenger Railway of Allegheny City, Pennsylvania. That year may be said to mark the beginning of the modern commercial development.

The latter road was about four miles long, one-quarter being of conduit construction and the remainder having a double trolley line on side poles, with a travelling trolley connected to the car with flexible cables. It presented unusual difficulties. There were thirty-four regular curves and numerous heavy grades, the maximum being over twelve per cent. and one averaging six per cent. for nearly a mile. The cars were equipped with two fifteen horsepower motors geared to the axles and overhung. The control was by resistance variation. This line was opened early in 1888 and continued in successful service for some time; but the conduit was finally abandoned, and a new equipment was installed with under-running trolley.

THE RICHMOND ROAD.

In the capital of the old Confederacy a new one was assaulted, but this time it was one of physical difficulties, adverse financial and operating conditions, and all the ills of a new and untried system. When my company took the contracts for roads at St. Joseph and Richmond we had little to show other than some blueprints, the machines used on the elevated railroad experiments, and some crude machines used in connection with storage battery operation, but confidence was strong and the contracts were taken under terms, price and guarantee easily placing them ordinarily in the "knave or fool" class, especially in view of the unprepared state of the company to undertake a work of such magnitude. I have, however, always had an abiding faith in the necessity of backing one's faith in a new development to the limit of one's capacity, and the need of this undertaking to break through the inertia of doubt and disbelief.

The Richmond contract called for the completion in ninety days of the equipment of a road having about twelve miles of

track, at that time unlaid and with the route only provisionally determined; the construction of a complete steam and electric central-station plant of three-hundred-and-seventy-five horsepower capacity; the construction of an overhead line; and the furnishing of forty cars with eighty motors and all the appurtenances necessary for their operation. This was nearly as many motors as had been installed on all the cars throughout the rest of the world. Thirty cars were to be operated at one time, and grades as steep as eight per cent. were to be mounted. Finally, the payment was to be $110,000—" if satisfactory."

Fortunately for the future of electric railways the difficulties ahead could not be foreseen, otherwise the contract might never have been closed. But disheartening as these were, great as was the expense incurred and grave as were the risks encountered, they were justified by the results, for the Richmond road, by common consent, stands as the prototype in almost every essential detail of the modern electric-trolley system, and its installation marked the real beginning of the great industry of electric traction.

The contract was made in May, 1887, and shortly afterwards I was stricken with typhoid fever, leaving for the time being the burden on my two principal assistants, Lieut. Oscar T. Crosby, a West Point graduate, and Ensign S. Dana Green, of my own Alma Mater, the Naval Academy, both of whom had resigned to enter the electrical field.

Although a hundred and one essential details were undetermined, during my absence everything possible was done, and on my way back from a convalescent trip to the West I had the pleasure of seeing one of my trusted men, David Mason, start a car on the track at St. Joseph, and immediately afterwards I resumed general charge of the work. I had not yet seen the Richmond road, but much of the track-work was finished, poles were set, many of the motors constructed, and experimental work on them and the controlling switches and trolleys was under way.

The construction syndicate was clamorous for operation to begin, excuses on our part were without number. I shall never forget my feelings when, after inspecting the improvised car sheds at one end of the line, I reached the foot of the steepest hill on my return, and faced a grade varying from four to ten per cent. and about a mile long. The condition of the track was simply execrable, built for profit, not for permanence. The flat twenty-seven-

pound tram rails, of antiquated shape, were poorly jointed, unevenly laid and insecurely tied, on a foundation of red clay. The many curves were sharp, some with a twenty-seven-foot radius; they had only one guard rail and spread easily. The car-house was an open lot on which were two roughly covered sheds. Altogether, I began to realize the extreme hazards, both electrical and financial, which had been imposed upon my company.

The history of the Richmond road has been too often written to dwell upon it at any length here. Suffice it to say that after experimental runs in the latter part of 1887 it was put into commercial operation in the beginning of February, 1888, and for a year there followed an experimental period of development which taxed the resources of the company to the limit.

The general features characterizing it may be briefly summarized as follows: A system of distribution by an overhead line carried over the centre of the track, reinforced by a continuous main conductor, in turn supplied at central distributing points by feeders from a constant-potential plant operated at about 450 volts, with reinforced track return. The current was taken from the overhead line, at first by fixed upper-pressure contacts and subsequently by a wheel carried on a pole supported over the centre of the car and having free up-and-down reversible movement. Motors, one to each, were centered on the axles, and geared to them; at first by single and then by double reduction gears, the outer ends being spring supported from the car body, so that the motors were individually free to follow every variation of axle movement and yet maintain at all times a yielding touch upon the gears and absolute parallelism. All the weight of the car was available for traction and the cars could be operated in either direction from either platform. The controlling system was at first by graded resistances, effected by variation of the field coils from series to multiple relations, and series-parallel control of armatures by a separate switch. Motors were run in both directions with fixed brushes, at first laminated ones placed at an angle, later solid metallic ones with radial bearing, and finally carbon, as proposed by Van Depoele.

The well-nigh heartbreaking experiences and the record of good and bad performances are largely matters of personal history, but the results accomplished soon commanded the attention of those interested in street transportation, most prominent among

whom at that time was Henry M. Whitney, President of the West End Railway of Boston, who was considering the adoption of the cable. He consented to come to Richmond, and accompanied by his associates stopped also at Allegheny City to see the underground conduit of the Bentley-Knight Company. The demonstrations made for his benefit were conclusive, the cable proposal was abandoned, and orders given for trial installations of both the overhead and underground systems to run from the Providence depot in Boston to the suburb of Allston.

Richmond's early troubles were buried under an immediate financial loss to my company of about $75,000, fully compensated for, however, in the subsequent growth of a great industry.

TELEPHONE TROUBLES AND THE BOOM.

To enliven the general situation, however, no sooner was the single overhead trolley with track return adopted than there began a battle with the telephone companies, who claimed the earth and all therein, which was fought to a legal and technical finish in twenty-seven States of the Union, as well as in England. The troubles which they were already experiencing because of the use of grounded circuits were intensified wherever there was an electric railway, partly because of sympathetic induction and partly because of derived circuits, which made the hissing and frying noises intolerable, to say nothing of frequent burn-outs of telephone circuits. Hence the trouble, but in the end we remained below, and they for their own salvation went up higher and adopted complete metallic circuits, for which improvement the electric-railroad men are entitled to the gratitude of the community.

Franklin Leonard Pope, in a historical sketch read before the Electric Club in 1891, referred to this pioneer enterprise in the following words:

> Laboring under enormous difficulties and drawbacks Sprague succeeded, by the completion and operation of this (Richmond) plant in establishing beyond peradventure the future supremacy of the electric street railway, and many of the characteristic features at that time designed and introduced by him have practically become standards in the modern system, and are found in nearly every one of the thousands of cars now in service.

OFFERED THE VAN DEPOELE COMPANY.

During the progress of the installation at Richmond the Van Depoele Company was offered to me by William J. Clark; but partly because of confidence in my own work and lack of appreciation of Van Depoele's, to say nothing of the fact that our resources were already taxed to the limit, the offer was not long considered, and shortly afterward it fell into the hands of the Thomson-Houston Company, which had only a short time previously entered the railway field.

The final success of the Richmond road, the rapid equipment of a number of others, and especially the adoption of electricity on the West End Road of Boston by Mr. Whitney, whose first installation was part conduit and part trolley, and to whom must be awarded the credit for initiating the modern consolidation of street railways, were followed by a period of extraordinary activity in commercial and technical developments, in which for a time the Sprague and Thomson-Houston companies were the principal competitors, more than two hundred roads being put in operation or under contract within two years. The contest between the companies was of the keenest sort and the methods of exploitation most varied; but in the general progress they were aided by the rapidly growing interest and belief in electric railways and the pressure exerted in many communities to abandon old practices. An amusing illustration is offered by the call for a mass-meeting held in New Orleans to demand that a line operated by mule power should change to the new system. The heading of the call, here reproduced, is typical of the South.

LINCOLN SET THE NEGROES FREE!
SPRAGUE HAS SET THE MULE FREE!

THE LONG-EARED MULE NO MORE SHALL ADORN OUR STREETS.

The progress made in the United States soon commanded the attention of the Old World, and work was begun along the same lines in Italy, where I installed the first road, the Florence-Fiesole, in 1889. A few days after the opening a car jumped a curve, killed and wounded about twenty people, and we were finally permitted to resume operation after installing a short-circuiting switch which could be operated by the conductor, thus permitting electric braking by reversal of the controller. The

first road in Germany was installed at Halle, by our agents, the Allgemeine Elektricitäts Gesellschaft, but it was not until a number of years later that there was any general adoption of the electric railway in the more conservative countries.

Meanwhile, the Sprague Company was absorbed in 1890 by the Edison-General Electric; and soon afterwards, embittered by personal experiences in an attempted suppression of my name and a suggested abandonment of the trollley in favor of the use of low-potential rails, and the proposed creation of a new motor, all failures, I severed my connection with it. The Edison Company was later combined with the Thomson-Houston Company in the General Electric. The Westinghouse Company had meanwhile actively entered the field, and for a number of years these great companies have done the larger part of the electric railway work in this country.

RECORD OF DEVELOPMENT.

The record of the succeeding years is largely that of an extraordinary industrial development, with continuous improvement in, and increase in size of, the apparatus. Form-wound armatures, proposed by Eickenmeyer, replaced irregular windings, and metallic brushes had given way to carbon, this single change, initiated by Van Depoele in 1888–89, going a long way toward making the art a success. Cast and wrought iron yielded to steel, two-pole motors to four, double-reduction gears to single, and open motors to closed ones protected by their own castings.

The horse and cable virtually disappeared on old lines, and new ones in great number were created, the overhead-trolley system being almost universally adopted. The conduit system used on a portion of the Allegheny and Boston lines had been abandoned; and although in 1893 a short line was tried in Washington on the Love plan it was not until the following year that work was begun in New York on the Lenox Avenue line, and finally carried to that successful conclusion which warranted its widespread adoption in that city under the auspices of William C. Whitney and Herbert H. Vreeland, and shortly afterwards in Washington under Connett. Abroad, a Siemens road had been in operation at Budapest since 1889. On account of the necessarily heavy cost of construction street-railway managers would not undertake any such

investment except under most favorable traffic conditions, and only when impelled by prohibition of the use of overhead wires.

INCREASE OF POTENTIAL.

Richmond and the many roads that were contracted for during the next few years were all operated on the system of direct supply, that is, by direct current without the intermediary of substations, and at voltages not exceeding 600 volts. While this was sufficient to meet the requirements of the times, in the very early days I realized the economic necessity of raising the working potential, especially if the matter of general railway electrification was to be attempted. This conclusion was illustrated in the potentials specified as required in a project to electrify the New York and Philadelphia Division of the Pennsylvania Railroad, as outlined in a paper read by me before the National Electric Light Association at Kansas in 1890.

Prior, however, to any serious consideration of this class of operation there began a rapid introduction of interurban railways, which was soon aided by applying the developments which had been made in polyphase transmission by Ferraris and Tesla, and in transformers and rotaries by Stanley, Bradley and others, which made possible the economies of alternating current transmission at high potentials and the advantages of direct-current motor operation, through the intermediary of step-down transformers and rotaries or motor-generators, all vital to long-distance and high-powered work where direct-current motors are used.

LOCOMOTIVES APPEAR.

Soon after the use of electricity for single cars had proved successful, heavier operations were naturally attempted, and as early as November, 1890, a line on the South London Road which was originally designed for cable was opened, the trains being pulled by electric locomotives equipped with a pair of gearless motors having armatures mounted on the axles of the drivers. Two years later the Liverpool overhead trolley was put in operation. Here the trains were composed of two-car units, each car having one motor, the two being operated by hand control. In the spring of the same year, 1893,. the Intramural Railway was constructed at the World's Fair, Chicago, where motor cars with

hand control were used to pull trail-cars, and a third-rail supply with track return was adopted.

In 1895 the Metropolitan West Side Elevated Road in that city was equipped on the same general plan. In the following year the Nantasket Beach Road, a branch of the New York and New Haven Railway, was put in operation, and in September the Lake Street Elevated of Chicago. Soon afterwards electric service was instituted on the Brooklyn Bridge, motor-cars being used to handle the trains, at first at the terminals and later across the bridge.

There were few attempts, however, to replace steam operation, and only occasionally were electric locomotives used for some special reason. Among the earlier ones in the United States was one of a thousand horsepower, designed by the firm of Sprague, Duncan and Hutchinson. This was provided with a pilot-lever pneumatic control, and was built in 1892–94 for Mr. Henry Villard, for experimental operation on a line out of Chicago which was never undertaken. A still larger locomotive was built by the General Electric Company and used for operating the trains in the Baltimore and Ohio tunnel in 1895.

THE MULTIPLE-UNIT SYSTEM.

Meanwhile, although for the time being out of active railway work, having taken up the problem of vertical transportation, that of electric elevators, I was keenly interested in the rapid-transit problem, and urgently advocated a four-track, underground, electric railway for New York. To silence the objections of a portion of the daily press, in February, 1891, I offered under heavy forfeiture to install, in four months, on the elevated road a train to be operated by a locomotive car, also one to be operated by motors under the cars with a pilot control, and to make an express speed of forty miles an hour.

All proposals which followed steam precedents seemed a pitiful falling short of the possibilities of electric-train operation. In the development of electric elevators I had adopted distant control of the main motor-controller from a master switch. On the first large contract, that for the Postal Telegraph Building in New York, I had provided for the supplemental control and operation of any elevator in the plant from a single master switch in the basement, with the resultant possibility of simultaneous movement of all of them from one switch.

While pondering over the elevated electric-railway train problem one day the thought suddenly flashed upon me: Why not apply the same principle to train operation? That is, make up trains at any length by the combination of car units, a part or all of them equipped with motors, but all equipped with train lines, without regard to number, end relation or sequence, and to control such trains from either end of any car by a master switch connected to the common train line.

The idea, sketched on a scrap of paper, marked the complete birth of this new method, then named and now everywhere known as the "multiple-unit system." Its great possibilities instantly absorbed my interest, for I saw the opening of a new epoch in electric-railway operation. Here was a way to give a train of any length all the characteristics of a single car, with every facility of operation demanded by the most exacting conditions of service and capacity.

FIRST EQUIPMENT IN CHICAGO.

After two abortive attempts to get the privilege to demonstrate the advantages of the system at my own expense on the Manhattan road in New York an unexpected opportunity suddenly arose in the spring of 1897, when I was requested to act as the consulting engineer of the South Side Elevated Railway of Chicago. A brief inspection of the layout showed a field ripe for multiple-unit application, which I briefly explained to Sargent and Lundy, the engineers, and to Mr. Clark of the General Electric Company, fortunately all old friends. I hastily drew up a report, the main feature of which was an argument in favor of the abandonment of locomotive cars and the adoption of individual equipment under common control—in short, the multiple-unit system. As evidence of my confidence I supplemented the report by an offer to personally undertake the equipment on the general plan outlined, which met with the indorsement of the engineers. The contract was not concluded until after I left for Europe, and then only after a bitter contest with various companies and under most onerous conditions, supplemented by a $100,000 bond for performance.

HARD CONDITIONS IMPOSED.

Among other things I was immediately to begin work on the entire equipment and to have six cars ready for operation, in two

months, on a standard track supplied by me, the manner of making the test to be prescribed by the officers and engineers of the road and to be to their satisfaction. Should the test not be concluded by the date set, or prove unsatisfactory, the contract could be cancelled. Further tests could be called for elsewhere and the remaining equipments were to be completed by specified dates. As soon as the power-house and road were ready there was to be another test of not less than twenty equipments under service conditions for a period of not less than ten days. Should these equipments prove unsatisfactory the right still remained for the railroad company to cancel the contract and to require waiver of all claims.

I did not return to New York until about the middle of June, so that most of my instructions for the trial equipments were by cable, and the actual preparation was made within about thirty days, despite a wholesale strike of the mechanics employed in the shops of the new Sprague Electric Company, which soon took over the contract.

On July 11, 1897, two cars were put into operation on the tracks of the General Electric Company at Schenectady, and on the 26th, the half-century anniversary of Professor Farmer's test of a model electric railway at Dover, my ten-year-old son operated a six-car train in the presence of the officers and engineers of the South Side Elevated Road at Schenectady.

In November a test train of five cars was put in operation in Chicago, and on the 20th of the following April twenty cars, seventeen of which (one in flames) were taken off during the day because of defective rheostats; but with the last three-car train I had the satisfaction of pushing a steam train around a curve. Three months later, a year after the Schenectady test, locomotives had been entirely abandoned and the whole one hundred and twenty cars were in operation.

The controllers for the original Chicago equipment were of the ordinary street-car type, operated by pilot motors automatically retarded by any excess of current in the motors during acceleration. The train line contained three speed- and two direction-controlling wires terminating in couplers at each end of the car. The disposition of the control wires and their connection to the master switches was such that whatever the number, sequence or end relation of the cars there was never any change in the connec-

tion of the speed circuits, while when any car was reversed in make-up position the direction-controlling circuits were automatically reversed. So, also, whatever the grouping of cars, like movement of the master switch with reference to facing the track produced like relative direction of movement. These principles are fundamental whatever the changes of physical details.

As an alternative physical construction the Westinghouse Company first used a step-by-step pneumatic motor to operate the controller, and later, on account of the increase of duty, both the General Electric Company, which finally absorbed the Sprague Company, and the Westinghouse Company replaced the single cylinder form of controller by a combination of individual contactors each under a magnetic blowout, although later there was a return to cylinder operation.

The multiple-unit system is now a fundamental essential, the world over, for all electric-train operation where two or more equipped cars or locomotives are controlled from a common source, and its value in dense rapid-transit service like the Elevated and Subway in New York is indicated by the enormous increase of capacity compared with any other method of operation, a practical result which could not be equalled in any other way on the present subways alone for less than $100,000,000 capital cost of construction.

MAIN LINE ELECTRIFICATION.

Following a serious accident in the yard tunnel of the New York Central road, the first important step in America in main-line electrification was taken when a new station was determined upon, and electricity adopted for operation at and for some distance from the main New York terminal, in 1902–03; and here again there was a radical departure in engineering practice. Up to that time all motors used for railway purposes maintained a fixed relation between the armature and the field, but when this project was finally taken up under the guidance of an Electrical Commission, presided over by the then vice-president, Mr. W. J. Wilgus, and of which commission I was a member, a plan for a new type of locomotive, proposed by Mr. Batchelder, was submitted by the General Electric Company. This called for the use of bi-polar motors, the fields of which, carried in a horizontal plane, were supported by and made an integral part of the locomotive frame,

and hence carried above the suspension springs. The armatures were rigidly secured to the axles, and the fields, with flattened pole pieces and a comparatively large air gap, were free to move vertically relative to the armatures. All brackets and gears were thus dispensed with and the motor reduced to the simplest form. Although ridiculed by many engineers at the time the new design was accepted and has proven entirely satisfactory. These locomotives were the first to be equipped with the multiple-unit control so that two or more could be operated together, the same as the suburban cars. On this equipment was first developed the W. and S. under-contact rail.

In Europe the first important main-line electrification projects were carried out on the polyphase system, with a high degree of technical skill, by the Ganz Company on the Valtellina and the Simplon Tunnel lines. On these the axle mounting was abandoned, and the motors were carried on the locomotive frame, being connected to the drivers by side rods.

ALTERNATING VS. DIRECT-CURRENT MOTORS.

As already stated, in the early days of electric railroading it was apparent that at the electric pressures commonly used, from 450 to 600 volts, the field of operation would be restricted by the large investment required for copper, not of course within ordinary city limits but when the distances became considerable. I had, therefore, advocated improvements looking to the raising of direct-current potentials. For a long time this seemed impracticable to many engineers.

Meanwhile, the system of polyphase alternating-current transmission, with conversion to direct current at substations through the intermediary of step-down transformers and rotary converters or motor generators, had been developed to such an extent that the field of operation from a single central station was materially broadened. Of course, there was the investment at the substations, by no means a small one, and many engineers ardently recommended the abandonment of all consideration of the use of direct current for interurban and trunk-line operation, and urged the adoption for this purpose of either polyphase or single-phase alternating-current motors, with direct supply at high potential on the trolley wire, speed control to be attained by the use of a step-down transformer or otherwise.

Among the engineers who became prominently interested in this technical development may be mentioned Lamme, Finze, Winter, Eichberg and Steinmetz. It was conducted along two or three different lines. One type, originally proposed by Thomson and known as the "repulsion" motor, had the field supplied direct at the full-trolley potential. This has been largely abandoned, although an alternative of this form was developed by European engineers, in which latter type a variable potential was supplied to the armature from a transformer.

Another, and more successful type, is the series-commutator motor, much like the ordinary direct-current motor, except that the iron in the magnets is laminated to prevent loss and the pole pieces have an additional compensating winding across their faces. The high-tension current from the trolley is transformed to low tension on the locomotive and speed regulation is obtained by the use of the rheostats or voltage variations on transformers. Naturally, there are many variations in detail introduced on the equipments actually installed for railway service.

The great difference of opinion among American engineers and manufacturers gave rise to bitter controversies, which rose to a climax at the time of the adoption of the single-phase series-commutator type of motor on the New Haven road, whose trains had likewise to operate over a considerable section of the New York Central tracks at their common terminal.

THE INTERPOLE MOTOR.

Having been in the forefront of this controversy, the outcome has been of special interest. During a long period of doubt among many as to the results of single-phase operation my attention was called to developments which had taken place in variable-speed, direct-current motors for ordinary industrial purposes by making use of my old interpole winding, localized on small extra poles carried between the main poles of the motors, and in consequence I urged a test of this practice on railway motors. The first results attained were so remarkable that I instantly saw the possibilities of a great increase in the potential which could be used in direct-current operation, and that if this improvement was carried to a logical conclusion the probabilities were that the economical requirements of the larger problems could be met by this system. On account of certain inherent defects in the single-

phase motor it also seemed likely that it would gradually be abandoned, and since its sole claim for use had been based upon the economy of installation and transmission direct current might maintain its supremacy not alone upon urban and interurban roads but also in trunk-line operation.

There was, indeed, the specific lack of capacity inherent to a single-phase motor, to combat which increased armature speeds were supplemented by air-blast cooling. But of course these were equally applicable to the more sturdy direct-current motor, and were soon adapted for it, so that the relative capacities for equal weight efficiencies and heating remains as originally indicated, at least where twenty-five cycles are used.

Despite this general fact the single-phase system, which attained an early vogue in Switzerland, has continued to receive the support of the engineers of that country in its use on the State Railways, generally with 15,000-volt trolley supply, but at the low frequency of fifteen cycles.

Lack of relative motor capacity does not characterize the polyphase motor, and it has received the support of Italian engineers in several of their major installations, comparatively low trolley potentials and low frequencies being used.

In the United States a notable example of use is that on the Great Northern Railways. One of the most ambitious attempts on this plan was that undertaken by two German companies, many years ago, on the Zossen Military Line, where was made the highest record for speed of a car carrying passengers—about 126 miles per hour—the current being collected at 10,000 volts from three overhead wires by sliding contact.

The multiplicity of conductors, however, distinctly militates against the polyphase trolley system as a solution of the larger railway problem, despite the high ratio of motive power to weight and the easy use of the motor for braking by regeneration, quite independently of other limitations affecting trunk-line transportation in general and the supply of power for such from central power plants as are also used for the industrial supply of light and power.

Additional methods of using single-phase alternating currents on the working conductor have been proposed and put into practice, but these eliminate the single-phase motors entirely. Among them is the introduction on the locomotive of apparatus for changing the energy of the single-phase trolley current into polyphase cur-

rent to be used in polyphase motors, as on the Norfolk and Western Railroad.

Conversion into a pulsating direct current by the use of a mercury rectifier carried on the locomotive has been tried out quite extensively on experimental equipment, and also the use of mercury rectifiers operated from polyphase currents at substations, in both cases in connection with direct-current motors.

On the whole, the experience of the past twenty years seems to have demonstrated the soundness of the conclusions advanced with regard to direct-current development, for while the New Haven system has been necessarily maintained and extended, many of the other single-phase motor installations in the country have been abandoned, and on the other hand some of the most difficult and extended freight lines, at one time deemed by many engineers barred to direct-current operation, have adopted direct current at from 2400 to 3000 volts working potential, as illustrated by the Butte and Montana Railroad and the six hundred miles on the Chicago, Milwaukee and St. Paul Railway, this latter being the most ambitious project thus far undertaken. Following in general a plan suggested in a study of electrification for the Sacramento Division of the Southern Pacific Railroad some years ago, the St. Paul uses the motors for regeneration and braking on down grades.

Nor is the vogue of the direct-current operation confined to the United States, for French and English commissions have reported in favor of its general adoption, and on the Midi Railway of France single-phase operation has been abandoned in favor of direct-current motor operation, the conversion of A. C. to D. C. current at the substations to be effected by large capacity mercury rectifiers.

Incidentally, the development of the automatic substation, with material elimination of attendance, and a general raising of line potential and consequent efficiency by a more frequent distribution of smaller conversion units, will add to the extent and flexibility of the direct-current system.

Finally, a recognition that railroads are but one of many diversified users of electric power, and that for financial and economic reasons common sources of supply should be utilized, will prove influential in determining that system which best lends itself

to the requirements in the matter of frequencies of the most economical high tension transmission.

THE FUTURE.

It has been said that the throb of the locomotive was the heart-beat of civilization, and so the hum of the motor may well be considered a song of emancipation. Every country with expanding resources owes its growth and prosperity largely to the development of its arteries for transportation, and its future will in a large measure depend upon the efficiency with which such continues to respond to the demands made upon them.

It has been predicted that, with normal growth, traffic requirements in the United States will be doubled well within a score of years, but already many of the trunk lines are within sight of the limit of capacity at terminals and portions of the rights of way, under existing conditions of operation. The transportation problem, therefore, promises to be one of the most serious which confronts railway and governmental execution.

Increase of capacity is the coming vital need, to be achieved where possible along existing lines and by existing methods, but where these fail then in the adoption of a motive power which permits material or even radical changes in train make-ups and operation, and increase of capacity.

The steam locomotive and its rival cannot be compared simply as machines, for there are inherent differences between them. However improved, the former remains a moving power plant, limited both as to its maximum and continuous rate of power development by the capacity of its boiler and a portable fuel supply. It is an independent entity, which fact has certain advantages but also certain disadvantages.

The electric locomotive, on the other hand, is a transformer of electric energy created at distant power stations and transmitted to it by stationary conductors. Thanks to the multiple-unit system any desired concentration of power units under a common control is possible, and any number of power plants, taking their energy from centuries-old and diminishing supplies, of increasing cost, or the annually renewed white coal of the mountains, can be joined together in common supply.

Already it has been conclusively demonstrated that with the electric locomotive any given mountain traffic can be handled with

a fewer number of units and at higher speeds; that it is capable of longer hours of continuous service under adverse weather conditions and with less terminal inspection and repairs; that train schedules can be increased not only because of the superior speed on heavy grades but because of the elimination of waits for coal and water supplies, with fewer lay-overs at a reduced number of passing points on single-track railroads; that there may be a material reduction of useless dead-tonnage haul; and that if there were universal electrification there could be saved at least one-half of the coal now used on railroads, which already amounts to a quarter of the total mined.

Among other outstanding facts it has also been established that any required amount of power can be transmitted over long distances with entire reliability and with limited losses; that it can be stepped down from very high to any required potentials at local centres of supply; that it can be distributed thence in the form of single or polyphase alternating, or direct current, the former by overhead conductors and the latter by both overhead and third-rail iron conductors; and that it can then be used in any form desired in the motive-power equipment—in short, that electricity itself, now a source of power and its character still unknown, is at once the most docile, tractable and universal servant of man.

But despite the enormous advances made and the results already accomplished it would be folly for the electrical engineer or the railroad man to assume that the limits of invention or development had been reached, as evidenced by the steady march of improvement to meet new problems and recent remarkable prophecies of things to come.

The urban and interurban fields, with the constant linking up of smaller systems into more extended systems, has gone on apace, but the trunk-line systems are still largely steam operated, and there are wide differences of opinion among engineers as to whether a single system will be dominant, and if so, what one, or whether the varying conditions and demands will be best met by specific solutions.

The financial question involved in the large cost of equipment cannot but remain a factor which will often prove controlling, for electrical operation will not be generally adopted except there be a commensurate gain of some kind. Where coal at low unit

cost is the source of power the gain in economy alone will not warrant the adoption of electricity on independently operated roads, but where coal is high in price or water power can be gotten at a reasonable cost then there is a valid reason for the change.

Excluding special cases, what will ultimately be constructively influential will be that need of increase in existing or available track capacity which I have already indicated, which is undoubtedly possible to a system which permits of individual and simultaneous control of a concentrated or distributed power plant greater than can be gotten by any other means, and can eliminate from its tracks the transportation of its fuel. It seems certain, however, that there must be coöperation in the important matter of power supply, and the general trunk-line problem will appear less formidable with the elimination of the requirements of installation of individual power houses, with their necessary reserves, and the use of current from great power plants properly linked together, which in addition to their reliability can make full use of the diversity factor in a multitude of demands.

Finer Dust Particles in Air.—A. L. MEYER, of Johns Hopkins University (*Jour. Ind. Hygiene,* 1921, iii, 51–56), has devised a simple method for the determination of the number of finer dust particles in air. The sample is collected in a Luer syringe which is graduated to 100 c.c. and has a total capacity of 160 c.c. The count of the particles is made in a Levy blood-counting apparatus. The syringe is thoroughly cleansed, then filled with distilled water free from air bubbles. This water is forced completely out, and 20 c.c. of distilled water are drawn into the syringe from a flask which is provided with a filter of cotton wool. A sample of air, with a volume of approximately 100 c.c., is now drawn into the syringe, and its exact volume is read from the graduations. The nozzle of the syringe is covered with a rubber membrane which is held tightly in place. After shaking vigorously for one minute with an up-and-down motion, the syringe is held in a vertical position; and the water is forced to the very tip of the nozzle, then withdrawn so that a small bubble of air is admitted. Any particles of dust which have adhered to the narrow region of the nozzle are also brought into suspension by the latter manipulation. The metal connecting piece is attached to the syringe; and one drop of the liquid is permitted to flow into the chamber of the counting apparatus. After the particles have settled, count is made of the number present in two fields, each one square millimetre in area. J. S. H.

SOME APPLICATIONS OF PHYSICS TO ORDNANCE PROBLEMS.*

BY

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IN a very recent number of one of our most popular magazines, founded, by the way, nearly two hundred years ago by the scientist and philosopher whose name this institution bears, Ex-Secretary Daniels gives three reasons for building dreadnoughts—they are first, gun power; second, gun power; third, gun power. In this statement Secretary Daniels confirms our view that a battleship is merely a gun carriage. The submarine is a special form of disappearing gun carriage. Were it not for the guns on board, the battleship and the submarine would have no reason for their existence.

It is the business of guns to throw projectiles. The only reason, therefore, for putting $635,000,000 into battleships now being built and to be built during the next three years, is that they may throw more projectiles, throw them farther and with greater accuracy than can their adversary. In olden times a "Man-of-War" could come to close terms with an adversary. Its fighting men could even board an enemy's vessel and, by cutless and pistol, fight red-blooded battles. Not so in these days. In place of trying to close in on an adversary the modern battleship seeks safety in distance—a distance secure from the enemy's guns, but sufficient for its own guns to work destruction. During the World War the chief naval engagements were decided by these conditions. In future wars the ranges will be greater. The accuracy must be correspondingly increased.

When we consider the vast amount of money which is expended in guns and projectiles, we feel justified in devoting time and energy to a study of scientific problems connected with their functions. My lecture this evening will deal with some experiments which have been and are still being carried on by the Ordnance Department and the Bureau of Standards—experiments having for their purpose the determination of (*a*) the forces ex-

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, March 31, 1921.

erted on a projectile by a rapidly moving air stream, (*b*) the retardation of a projectile as a function of the many variables upon which it depends, (*c*) the pressure of the explosion in a gun and its rate of variation with time, and (*d*) the expansion of a gun during firing.

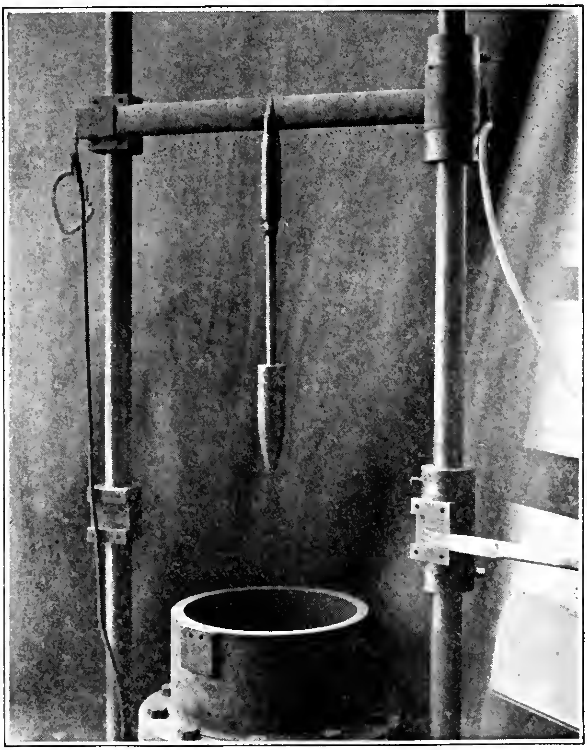
What are the factors determining the flight of a projectile? Obviously they are the velocity, angle of elevation, weight of projectile, and resistance of the air. If there were no air resistance, all projectiles would have the same range and time of flight, given the same muzzle velocity and angle of elevation. The .30-calibre rifle bullet, for example, would have a range of 43 miles and would have at the end of its flight the same energy and destructive action as at the beginning. But the *resistance* of the air, which is a very comprehensive term involving the shape, distribution of mass, spin and velocity of the projectile, as well as the density and temperature of the air, robs this small projectile of nine-tenths of its range.

Before the World War we had contributed nothing to our knowledge of the resistance of the air for projectiles. The law of air resistance, upon which are computed all our range tables both for the army and navy, is taken from foreign sources. In determining this law the classical method of firing through screens was used. As will be shown later, this is a method which has not been carried to great precision, and which as conducted in the past can lead to very incomplete results.

Without going into the history of the matter, we will consider first the method which has been used during the past two years for determining the forces exerted on a projectile by a rapidly moving air stream. Just a word as to the power required to produce the necessary air stream. A wind of 60 miles per hour, nearly 90 feet per second, is regarded as a gale. Power goes up with the cube of the velocity. To produce an air stream of 600 miles per hour or 900 feet per second would require 1000 times the power called for to give the 60-mile gale. To produce a speed of 1500 feet per second, we would have to increase the power 4600 times. It can easily be computed that the power required to produce a one-foot diameter wind stream of a velocity of 1200 feet per second, if we assume that 30 per cent. takes the form of thermal energy and only 70 per cent. takes the form of the desired kinetic energy, is 8600 H. P., or

6300 kilowatts. If this had to be paid for at an electric light rate of 10 cents per kilowatt hour you can see that the cost would be more than ten dollars a minute. Of course we do not have to pay such a rate, and fortunately, through the courtesy of the General Electric Company, we have been able to utilize the commercial

FIG. 1.

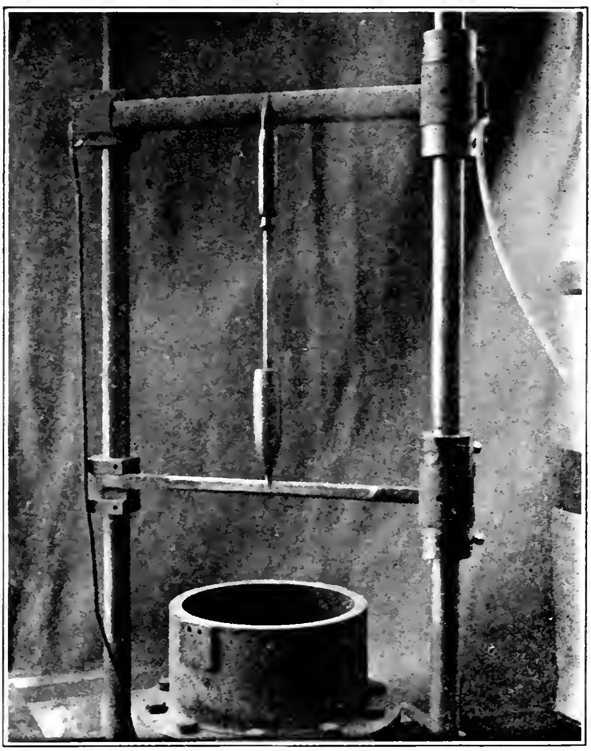


tests of the compressors so that the Government has been called upon to pay for only a small part of the power it has used.

The apparatus now used for measuring the forces on the projectile is illustrated in Fig. 1. The projectile is attached by a steel spindle to a steel piston working in a cylinder, the latter being attached to a horizontal bronze bar which can be moved in and out, or up and down, in the wind stream. The pressure of the air above the piston can be regulated and measured. Hence, when the up-

ward force of the air on the projectile is equal to the weight of the moving system, the piston moves up or down in the cylinder, or a "balance" is obtained. As far as this "weighing" is concerned, the accuracy depends upon the precision of fit of piston and cyl-

FIG. 2.



inder. This precision is such that although only lubricating oil is used between the surfaces, air does not leak in or out to any appreciable extent. At the same time, a difference of force of 0.04 pound will cause the piston to change from an up to a down motion, or vice versa.[1]

[1] Under the direction of Dr. L. J. Briggs, of the Bureau of Standards, who is collaborating in these experiments, these cylinders and pistons were made by Mr. W. H. Cottrell, to whom is due great credit for excellent workmanship.

But the projectile is held by a spindle upon which the moving air stream exerts some force. In order to take account of this force, the projectile is attached at its nose to a small bar as shown in Fig. 2. The spindle, free to move vertically, is placed immediately behind the projectile. The force on the spindle and piston can then be found.

A hollow cylinder can replace a solid one. We can then measure the impact pressure in the air stream, or, mounting the projectile as in Fig. 2, we can measure the pressure at the base and across the base of a projectile. In this way we can compute the force due to the base and the portion that this is of the total.

The velocity of the air and its temperature, after it has issued from the orifice, are computed by the use of the ordinary formula holding for adiabatic expansion, *viz.*,

$$V^2 = 2\,J\,C_p\,K_i \left\{ 1 - \left(\frac{po}{pi}\right)^{\frac{Y-1}{Y}} \right\} = 2\,J\,C_p\,(Ki - K_o)$$

where

V = velocity of air in metres per sec.
J = mechanical equivalent of heat.
$= 4.18 \times 10^7$ ergs/gram calorie.
C_p = specific heat of air at constant pressure = .240.
Y = ratio of specific heats = 1.405.
K_i = temperature of air in pipe (Kelvin).
K_o = temperature of air in jet.
P_i = pressure inside of pipe.
P_o = pressure in jet = barometric pressure.

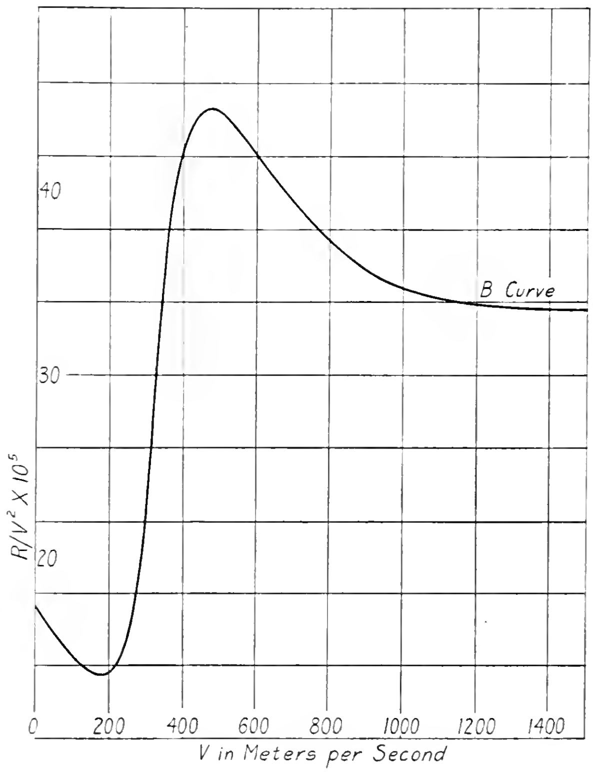
It is necessary to measure the pressure and temperature of the air in the pipe below the orifice, *i.e.*, before expansion. For this purpose a number of pressure gauges and thermo-elements are used. A potentiometer, a galvanometer (suspended so as to be undisturbed by the very pronounced vibrations of the building), and an air pump capable of producing suction or pressure, are also necessary. Photographs of the air waves about the projectiles, especially at high velocity, give an indication of the disturbing causes and also provide a check upon the computed air velocity.

There are a great many variables in this experiment, and there are a great many corrections to be applied and standardizations to be made. But finally we can say that we know the force which an

air stream of a certain velocity, density, and temperature will exert on a projectile of a certain specified form. For a number of definite forms we know the law of air resistance between the ranges of velocity so far used, *i.e.*, from 200 to 380 metres per second (about 600 to 1200 feet per second). And we know the effect upon the resistance of adding a rotating band to the projectile fore or aft.

But it may be argued that we must have known the law of air

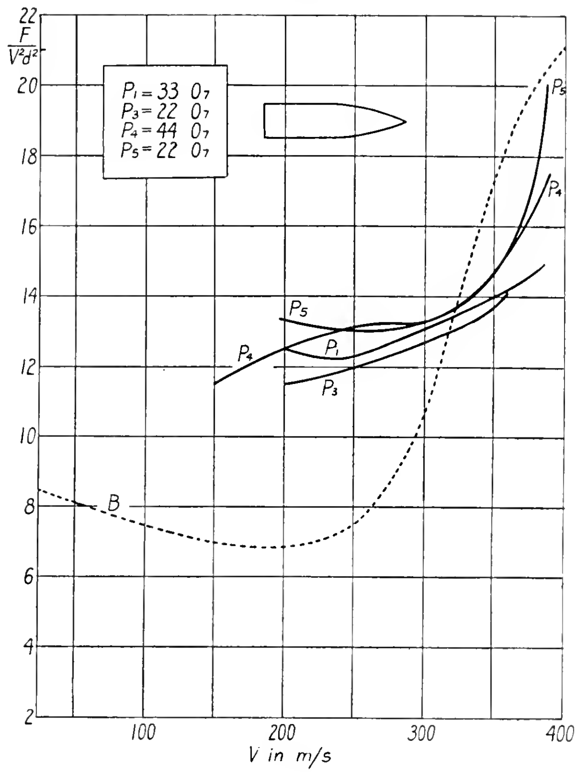
FIG. 3.



resistance for years, otherwise we could not have constructed range tables. It is true that we follow the French law in this work (we have never determined any law whatever for ourselves), but it will be seen in Figs. 4, 5, 6 and 7 that that law does not hold even approximately for modern projectiles, within the limits of the velocity we have used. The French write the law in the form

$R = c\rho d^2 V^2 B(V)$. Hence $R/V^2 = c\rho d^2 B(V)$ Where $B(V)$ is a function of V which when plotted has the form of a dotted line in Figs. 4, 5, 6 and 7, and the full line in Fig. 3.[2] Now, projectiles

FIG. 4.



illustrated in Figs. 4, 5, 6 and 7 may be regarded as modern, and

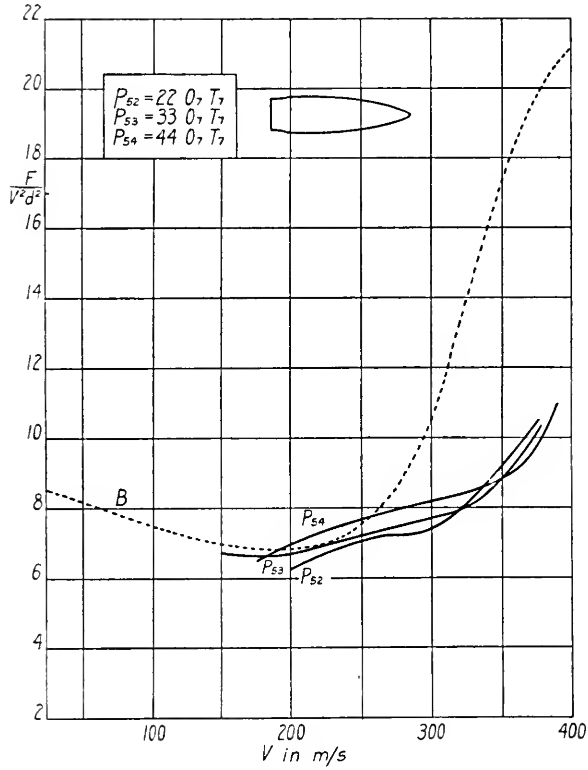
[2] The law of dimensions requires that the force take the form

$$R = \rho v^2 l^2 f\left(\frac{\mu v l}{\rho} \quad \frac{v}{c}\right)$$

for any given form of projectile which has a linear dimension l, moving with velocity v in a medium of density ρ, viscosity μ, and compressional wave velocity c (velocity of sound). Here f is an unknown function which may be represented by $R/\rho v^2 l^2$. The B curve is this function for the projectiles used by the French in its determination. Its rapid rise in the neighborhood of a velocity of 350 metres per second indicates the influence of the *compresional* term in the dimensional equation.

for these the resistance law departs widely from the B curve—the curve which is the basis of all our ballistic computations. These curves also show that for low velocities ($V = 200$ to 250 metres per sec.) the force due to the air does not depend very much upon the form of the nose, but that it does depend very critically upon the form of the base. Thus, boat tailing a projectile 9° cuts the force

FIG. 5.



in half for $V = 200$ m/s. At low velocities the 9° boat tailing is rather better than a 7° or a 5°, but this advantage soon disappears as the velocity increases. Our curves suggest, though they do not in any way prove, that at high velocities the retardation of a boat-tailed projectile is not much less than that for a square base.

It is clear then that when we speak of the "best form" projectile we must specify the velocity for which this term applies.

The important part played by the base of the projectile is fur-

ther made evident by the measurement of the pressure of the air across the base. For a square base projectile, the pressure is fairly constant at all points across the base. This pressure is negative when compared with atmospheric pressure and therefore is suction. The data of Table I show that at low velocities the force due to the

TABLE I.

Data showing pressures of the air at the base of a projectile.

Projectile No. 3, square base. 7 calibre ogive.

V m/s.	Suction at base in cms., Hg.	Fo= Force due to suction at base.	F= Total force.	Ratio F_0/F.
198	2.3	1.53	1.99	.77
230	3.2	2.19	2.52	.80
285	5.3	3.51	4.00	.87
298	5.3	3.40	4.40	.80
322	5.5	3.65	5.40	.70

base is four-fifths of the total force for a 7-calibre ogive projectile. If the area of the base is decreased by boat tailing, and if, as our measurements show, the suction also decreases, then the force due to the base is greatly decreased and the total force on the projectile is similarly affected. Table I shows the suction in centimetres of mercury at the base of a projectile. To interpret this suction in pounds per square inch, one has to divide the number of centimetres of mercury by 5.17.

The data shown in Figs. 4, 5, 6 and 7 were obtained without any rotating band on the projectile. The addition of a rotating band may greatly increase the force or may have no effect, depending upon its position. For a square base projectile, a band flush with the base increases the force by from 10 to 15 per cent. But if the band is placed slightly away from the base there is no appreciable increase over the case of no band. For a boat-tailed base, placing the band at the beginning of the bose cone increases the force from 20 to 50 per cent. In the case of a long-coned ogive, a band placed at the end of the ogive may produce an increase in force of over 50 per cent., while two bands at the end of the base and nose cones may produce an increase of 100 per cent. Clearly, then, small rregularities in the form of a projectile may bring about a surprisingly large increase in the retardation. Table II shows

some of the variations of force due to the positions of the rotating band.

TABLE II.

Variation in force due to change in position of rotating band. Distances of the band measured from the base.

Projectile No. 5, square base, 2-inch dia., 7 calibre ogive.

V = 215 m/s			V = 235 m/s			V = 280 m/s		
Position of band	force/V^2	Ratio	Position of band	force/V^2	Ratio	Position of band	force/V^2	Ratio
no band	530	1.00	no band	520	1.00	no band	535	1.00
0	580	1.10	0	590	1.13	0	620	1.16
.2 inch	520	0.98	.2 inch	534	1.03	.2 inch	570	1.07
.3 "	530	1.00	.4 "	520	1.00	.4 "	540	1.01
.5 "	540	1.02	.6 "	535	1.03	1.0 "	560	1.05

Proj. No. 52 2-inch dia. 7 calibre ogive 7° boat tailed

V = 250 m/s			V = 280 m/s		
Position of band	force/V^2	Ratio	Position of band	force/V^2	Ratio
no band	29	1.00	no band	30	1.00
1.00 inch	37	1.26	1.00 inch	40	1.33
1.25 "	35	1.20	1.5 "	37	1.23
			2.0 "	38	1.26

Projectile with coned ogive (20° total vertical angle).

V = 280 m/s			V = 260 m/s			V = 280 m/s		
Proj. No. 23 5° boat tail			Proj. No. 29 7° boat tail			Proj. No. 35 9° boat tail		
Position of band	force/V^2	Ratio	Position of band	force/V^2	Ratio	Position of band	force/V^2	Ratio
no band	394	1.00	no band	326	1.00	no band	283	1.00
1.0 inch	432	1.10	1.0 inch	413	1.27	1.0 inch	434	1.53
1.5 "	418	1.06	1.5 "	370	1.13	1.5 "	320	1.13
2.0 "	418	1.06	2.0 "	378	1.16	2.0 "	320	1.13
at ogive	516	1.31	at ogive	562	1.72	at ogive	450	1.59
			band at each cone...				580	2.05
			two bands midway between cones...				332	1.17

The forces platted in the curves here shown were measured when the projectile was held nose-on to the air. There have been indications that when the projectile was inclined to the air stream,

the force was greatly increased. For example, in one case, when a projectile weighing nearly fifty pounds was in the air stream, the nose-on force was a little over forty pounds. There was then a down force on the spindle. But as the projectile was being taken out of the air stream it was set swinging slightly. The air caught it on one of its swings and threw it up several feet, breaking off in that motion the steel spindle holding the projectile to the balance arm. It was evident that the inclined force must have been at least twice as great as the weight of the projectile.

By attaching the projectiles to the spindle at an angle to the axis, the force in the original direction of the air stream may be found for an inclined position. The data in Table III have recently been

TABLE III.

Variation of force due to inclination of projectile.

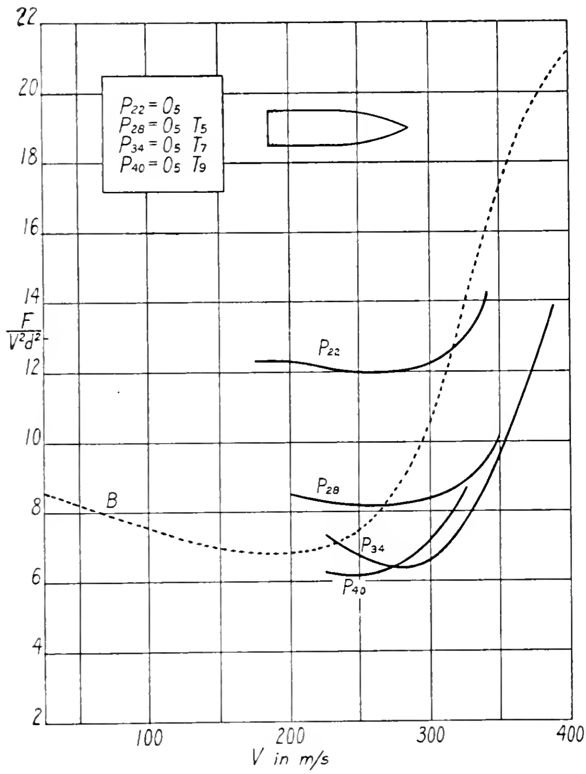
Proj No. 53 V=200 m/s					Proj. No. 1 V=200 m/s				
0°	2.5°	5°	10°	15°	0°	2.5°	5°	10°	15°
255	287	345	475	660	410	500	530	715	880

Proj. No. 53 V=270 m/s					Proj. No. 1 V=270 m/s				
0°	2.5°	5°	10°	15°	0°	2.5°	5°	10°	15°
5.2	5.5	6.3	8.1		8.4	9.8	10.2	14.9	

obtained and may require revision. These measurements show that the retardation of a projectile may be increased two and one-half times by a change in direction of the axis of the projectile through 15 degrees. Now, ballisticians have never taken any account whatever of the change of inclination of the axis of the projectile to the wind. They have regarded the projectile very much as if it were a sphere, *i.e.*, as if the force on the projectile was independent of its orientation. But our data show how serious an error may be made in following that assumption. At high altitudes, the wind velocity may be very large and may easily cause a 15-degree attack of air upon a projectile. In such a case, if the projectile is a stable one, its rapid rotation will cause the nose to precess about the apparent direction of motion of the air, and it may in time meet the air nearly

nose-on, but it may continue to have a large yaw, in which case its retardation will be several times as great as it would have been had it moved nose-on to the air. The experiments with the air stream not only give quantitative results for the forces on projectiles but they also show quantitatively, by means of photographs, the condi-

FIG. 6.

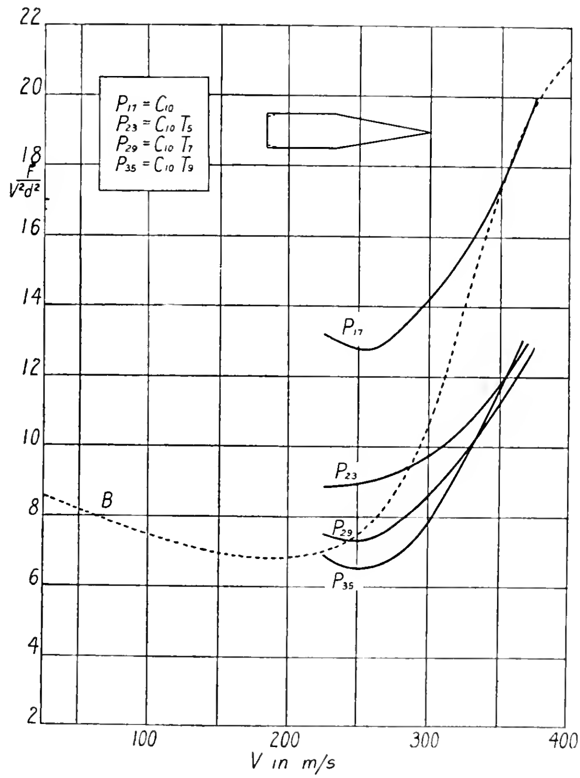


tion of the air round a projectile. (Here the lecture was illustrated with a number of lantern slides of bullets in flight taken by means of an electric spark source, showing the shock waves around bullets of different shapes, and showing how a bullet is forced away from straight line motion when its axis becomes slightly inclined to the nose-on position. Photographs were also shown of the air waves around projectiles in the air stream. These made evident the features of the projectile which were sources of wave motions in

the air and therefore indicated how the form of projectile could be improved.)

The photographic evidence just discussed shows that a projectile becomes inclined to its direction of motion. The wind stream experiments show that for an inclined direction the force on the projectile due to the air is greatly increased. It is necessary then to

FIG. 7.



study the gyroscope action of the shell, the inclination of its axis to its direction of motion, *i.e.*, its yaw, and to the variation of this angle with time. This problem, that is, the problem of the stability of a shell, is being studied by Mr. R. H. Kent, at the Aberdeen Proving Ground.

It is clear from everything that has gone before that the whole story of a projectile is not told by a study of the forces on it as it is

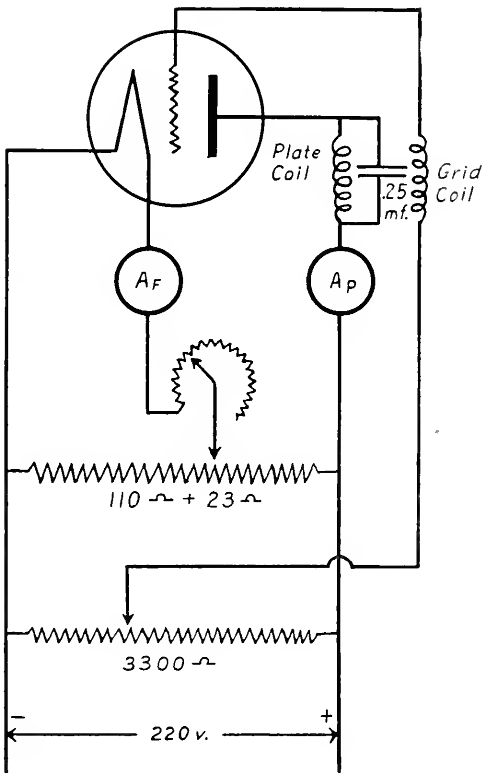
held in an air stream. It is advisable to supplement that information with data obtained from actual firings of a projectile. For this purpose the writer devised a chronograph and a method capable of measuring with great precision the velocity of a projectile at various points along its path.

As has been stated, the method of measuring the velocity of a projectile has been to fire through wire screens, thus breaking a wire and hence an electric current. The breaking of this current dropped a rod or made a signal on a revolving drum. It was clear, however, that the wires might be broken by the air waves in front of the projectile or might not be broken, if at all, until the projectile had passed completely through the screen. Thus the distance between the screens was always in doubt. Moreover in earlier methods the time was not accurately measured. About the end of 1918 the writer proposed to physicists at the Bureau of Standards and to army officers that it was unnecessary for the projectile to make or break electric contacts, that its magnetic effect in passing a station could be registered. He was assured, however, by those with whom he discussed the matter that the experiment had been tried and that the effect could not be obtained. (As a matter of fact this method was being used in England at that time, though the writer did not know this for months afterward.) Procuring apparatus the writer carried through preliminary experiments which showed that the effect could be obtained and registered by means of a string galvanometer.[3] Having made certain of the possibility of registering the magnetic effect the writer then turned his attention to a time source. The ordinary procedure is to use a tuning fork driven by an electromagnet, periodically operated by an electric contact on the fork or on a master fork. A study of this time source showed that the electric contact produced irregularities which had to be eliminated. Then he proposed a method of operating the fork by means of a thermionic vacuum tube. (A method rather similar to this was adopted in England about this time but without the writer's knowledge.) After a little study it was found that the essential feature of this method was to use two electromagnets, one in the grid circuit and one in the plate circuit; the former to be influenced by the motion of a prong of the fork, the latter to drive the fork. Fig. 8 shows a diagram of the wiring as finally modified

[3] The first photographic record for a projectile dropped from a height passing through a solenoid was obtained by the writer by means of an oscillograph.

by Doctor Eckhardt, of the Bureau of Standards, and members of his unit, who have improved the earlier conditions.[4] A tuning fork driven in this way will operate for hours with uniform amplitude, and therefore it can be calibrated with the highest accuracy. Thus time in intervals of 0.001 second can be recorded photographically on a revolving film.

FIG. 8.

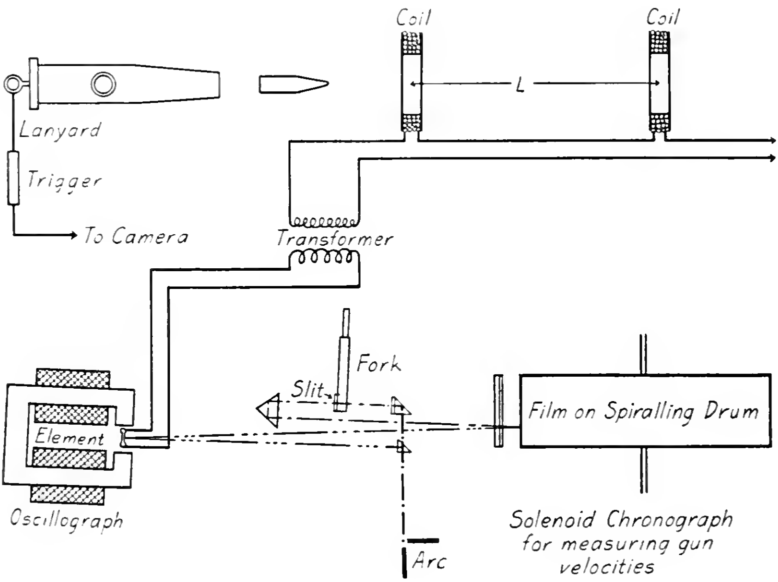


The first magnetic effects due to a shell passing through a solenoid were obtained by the writer at the Aberdeen Proving Ground in August, 1920. They were recorded by means of a string galvanometer. At first it was thought necessary to use a current in a primary coil to magnetize the shell and to use a secondary coil to register the shell's passage. Then it was found sufficient to mag-

[4] I am indebted to Doctor Eckhardt for the diagrams and photographs illustrated in Figures 8, 9, 10, 11, 12.

netize the shell before placing it in the gun. In some cases the change in the earth's flux through the coil due to the passage of a shell (shells from 3 to 6 inches in diameter have been used) was sufficient, and owing to the fact that the effect was easily obtained and that it was difficult to get damped motion in the strings of a galvanometer, an oscillograph was substituted for the former instrument. Fig. 9 shows the wiring arrangements for this experiment. The assembled apparatus as used in the laboratory

FIG. 9.

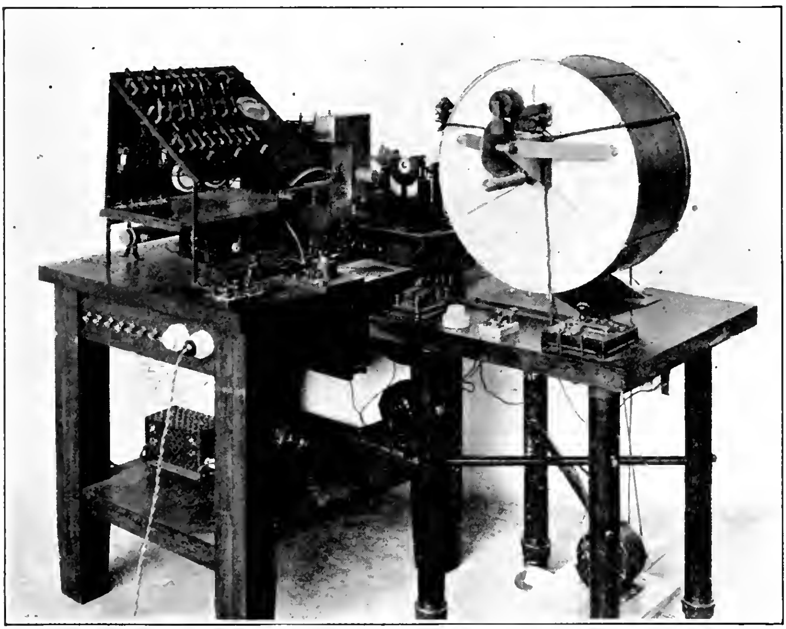


is shown in Fig. 10, and a separate view of the rotating spiralling drum in Fig. 11. In this latter view is seen an ingenious magnetic clutch due to Doctor Karcher, of the Bureau, by means of which the rotating drum can be made to spiral at any given signal. This is an improvement over the mechanical method which the writer used on the earlier drum.

There are a number of interesting mechanical details connected with this apparatus, the evolution of which we have not time here to describe. In the end it may be said that at a given signal, the shutter to the drum can be opened, the gun fired, the revolving drum

can be started spiralling and stopped spiralling at a later signal. The magnetic record of the shell as it passes successive stations is shown by the curved line [5] in Fig. 12. The cross lines are time signals 0.001 second apart. It is clear then that the velocity and therefore the retardation of the shell at numerous points along its path can be measured with high accuracy. As a result of the experiments with

FIG. 10.



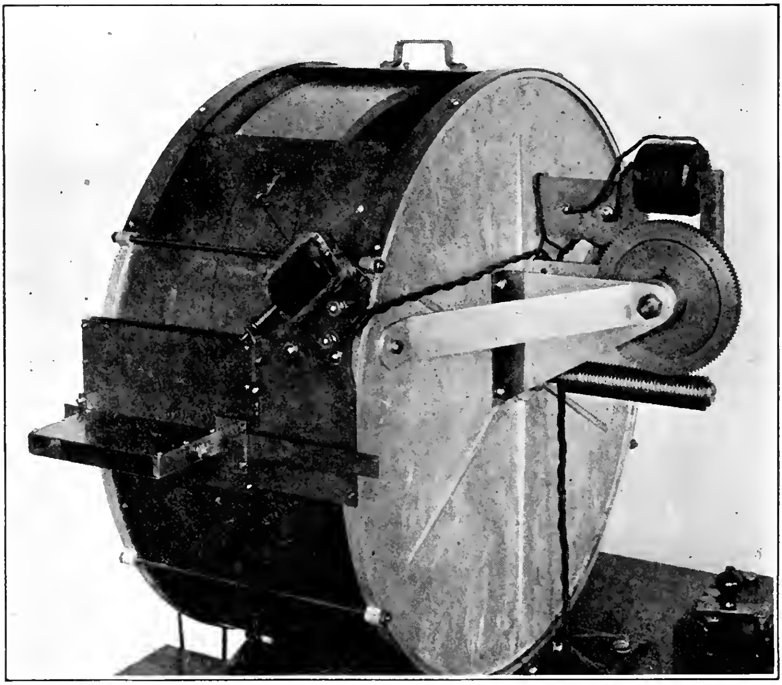
this chronograph it is expected that we will be able to state the retardation of a projectile as a function of its form, velocity, spin, distribution of mass, and the variables denoting the condition of the air.

Turning from problems connected with the projectile to those connected with the gun we find a number claiming our attention. The first is to measure accurately the pressure in a gun and its

[5] If one were certain that the shell passed through the solenoids centrally nose-on to the air one could measure its velocity at each solenoid by the time between the maxima displacements of the curve for that solenoid. This method however would give only a rough approximation to the velocity.

variation with time. Only one gage which can be used in large guns has so far been devised, *viz.*, that due to Doctors Curtis and Duncan, of the Bureau of Standards. It has, so the writer feels, certain defects which ought to be avoided. About two years ago the writer proposed to the technical staff that the piezo-electric effect of quartz be used for this purpose, and he outlined a method which could be followed. He proposed that the charge generated

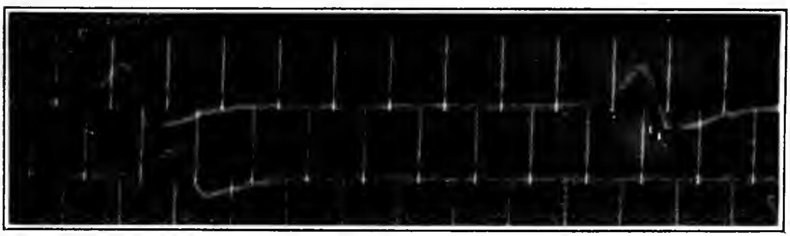
FIG. 11.



by the pressure be led to the grid-filament circuit of a suitable electron tube or amplifier, and that the resulting variations of the plate current be recorded by means of a sensitive, high-frequency, critically damped oscillograph. It would be necessary of course to connect the metal coating of the quartz plates to the grid so that the latter could be negative and otherwise to ensure high insulation in the circuit. Moreover it would be necessary to use a tube so that a linear relation would obtain between grid voltage, charge and plate

current. For this purpose the writer secured a resistance-coupled ampifier designed to give such a linear relation. This special amplifier, however, would only have to be used where small variations in pressure were desired. The large variations in pressure occurring in a gun could probably be recorded using only a single, rather large triode or pliatron. A pressure gage housing was conducted at Aberdeen, designed to transmit to the quartz plates about one-fiftieth of the total pressure in the gun. But tests at the Bureau on the quartz plates, which were secured by the Ordnance Department after a considerable search, showed that they could withstand the total pressure in the gun. Moreover it was found that there was a linear relation between the charge on the plates and the applied pressure

FIG. 12.

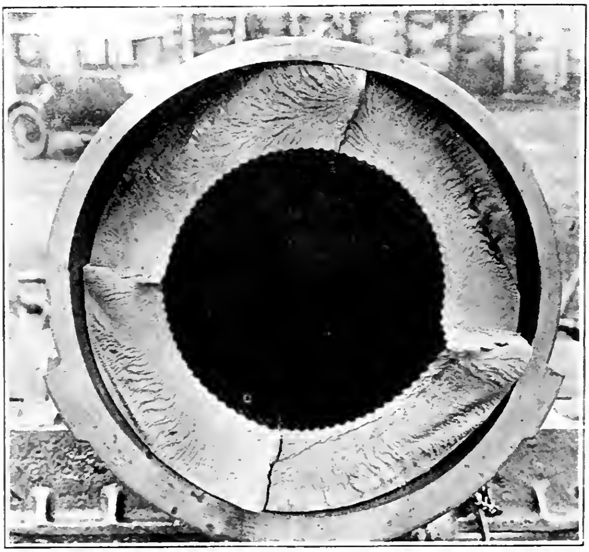


up to 50,000 pounds per square inch. These discoveries made possible other methods of recording the pressure than that first proposed. The Bureau has just obtained a time-pressure curve by means of this quartz crystal gage in which the quartz was subjected to the entire pressure in a bomb. The record was made by a very sensitive, long-period galvanometer, the rate of change of deflection of which was proportional to the pressure.

The apparatus just described can also be used to measure the expansion of a gun during firing and its variation with time. For years it has been the custom at proving grounds to "star gage" a gun (*i.e.*, to find its internal diameter) after a certain number of rounds have been fired. This gives the total change in the internal diameter due to erosion and to the expansion of the gun beyond its elastic limit during firing, but it gives no idea of the change of the diameter during the firing. The necessity of such measurements can be seen when we remember that we have no complete explanation of the bursting of certain guns. The popular notion is that the

powder gases experience difficulty in forcing a projectile out of a gun, and that in consequence the pressure rises until it is sufficient to burst the gun by a kind of hydrostatic action. That the action is not static, but often is due to a surging of waves back and forth in the gun, may be seen from a number of photographs of burst gun. Fig. 13 shows the cross section of a gun burst by a small charge after having been previously fired at full charge. The markings show a symmetry which can be accounted for only by a

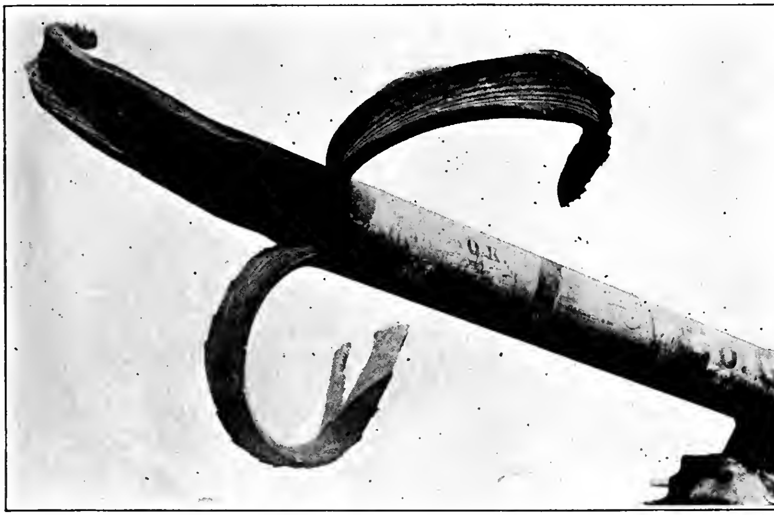
FIG. 13.



corresponding symmetry of stresses, and this could hardly have been due to a condition during manufacture. It seems more reasonable to suppose that the gun was thrown into vibration by the pressure waves. The effect of these vibrations would be greatest at the muzzle and at other points where there are abrupt changes in mass. That the disruption of the gun generally begins at the muzzle is made evident by many photographs in the possession of the War Department, one of which is shown in Fig. 14. That there are standing waves in the barrel of the gun is strongly suggested by Fig. 13. In any event the measurement of the expansion of the gun during firing and its variation with time is a matter of prime importance.

There have been discussed here a few problems which depend for their solution on the applications of precise experimental methods of modern physics. It is very obvious that the domain embracing warfare of to-day and of the future to which can be

FIG. 14.



applied such methods is very large. However reluctant scientists may be in identifying themselves with war activities they cannot fail to be stimulated by the challenge which these problems throw out.

Microanalytical Methods in Oil Analysis. AUGUSTUS H. GILL and HENRY S. SIMMS, of the Massachusetts Institute of Technology (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 547–552), state that very close analytical results for the saponification number of an oil may be obtained with a sample weighing 15 milligrams, about one one-hundredth the sample usually taken. Likewise very close values for the iodine number may be obtained with a sample of 11 milligrams, approximately one-thirtieth the amount usually used. The specific gravity may be determined on 1 gram of oil. These micro methods are of value when only a small portion of oil is available for analysis, for instance, when oil is extracted from leather, then analyzed.

J. S. H.

Nitrocellulose for the Manufacture of Artificial Leather.—W. K. TUCKER (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 623–624) states that nitrocellulose for use in the manufacture of artificial leather should have a nitrogen content between 11.5 per cent. and 13 per cent., with an average of 12 per cent. Its ash content should not exceed 0.4 per cent. The nitrocellulose is applied to the cloth base as a solution. The chief solvents used are ethyl acetate and acetone oil which is a mixture of methylethylketone with smaller amounts of acetone and related compounds. The solvent is usually diluted with either benzene from coal tar or benzine from petroleum. The amount of actual solvent in a solution rarely exceeds 30 per cent. and may be as low as 10 per cent. The solution is usually prepared so that its viscosity is approximately 40 seconds, *i.e.*, about 40 seconds are required for a steel ball five-sixteenths of an inch in diameter to drop through a column of the solution 10 inches high. The solution preferably should have a temperature of 25° C. during this test. J. S. H.

Thermal Decomposition of Oil Shales.—RALPH H. MCKEE and E. E. LYDER, of Columbia University (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 613–618), have studied the changes which occur during the destructive distillation of oil shales. They find that petroleum oils are not a primary product of the process. The pyrobitumens of the shale first are converted into a heavy solid or semisolid bitumen; this change takes place at a quite definite temperature, thus it occurred between 400° and 410° C. in the Colorado oil shale used in the experiments. The petroleum oils are then formed by the cracking or cleavage of this heavy bitumen. J. S. H.

Discoloration in Canned Sweet Potatoes.—EDWARD F. KOHMAN, of the Research Laboratory of the National Canners Association (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 634–635), finds that the black discoloration in canned sweet potatoes is due to a reaction between a tannin-like substance in the sweet potatoes and ferric salts derived from the iron of the can. Since access of oxygen is prerequisite for the formation of ferric salts, cans with tight seams are essential in the canning of this product. J. S. H.

Death of Lady Brewster.—Lady Brewster, the second wife of Sir David Brewster, died recently at the age of ninety-four. She was married to Sir David in 1857, when he was seventy-six and she about thirty. A daughter was born to them a few years later. Brewster died in 1868. He was one of the most distinguished physicists of his time, his work being especially in optics. He constructed the first lens stereoscope and perfected the kaleidoscope. He also made many important researches in polarized light and devised important improvements in the British lighthouse system.

H. L.

A MECHANICAL FREQUENCY-METER OF TELEPHONIC RANGE.*

BY

A. E. KENNELLY, Sc.D.

Member of the Institute.

and CH. MANNEBACK.

In the Journal of The Franklin Institute for May, 1919, Dr. L. V. King described and illustrated a form of mechanical frequency-meter which he called a "sonometer." His illustration of the device is reproduced in Fig. 1, ACB is a fine steel wire fastened at one end to the top of the cathetometer and soldered at the other end to a known weight W + W. This wire is supported in front of a telephone electromagnet T energized by the alternating current whose frequency is to be determined. The position of the bevel edge C is adjusted until, with the electromagnetic T excited, the wire BC is set into resonant vibration. The frequency of the exciting current is then

$$f = \frac{1}{2l} \sqrt{\frac{T}{m}} \quad \frac{\text{cycles}}{\text{sec}} \qquad (1)$$

where T is the total tension on the wire in dynes.
m– the linear mass of the uniform wire in gm/cm.
l– length of the vibrating segment BC in cm.

DESCRIPTION OF THE FREQUENCY-METER.

The laboratory frequency-meter here to be described is a development of the King sonometer, undertaken in the electrical engineering laboratories of the Massachusetts Institute of Technology.

In the King sonometer described, the linear mass was 1.373 gm/cm., and the available range of frequency was 360 to 1600 cycles per second.

The final form of the instrument is shown in Fig. 2. The wire used was a silver-plated steel wire, known as a " black diamond " string or " guitar B " as furnished by the National Musical Co., of New Brunswick, New Jersey, having a diameter of 0.350 mm

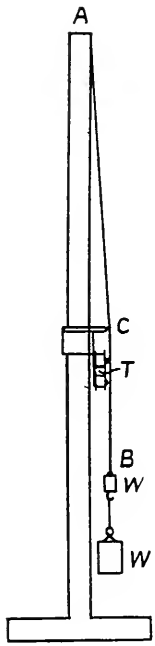
* Communicated by Dr. Kennelly.

which was entirely uniform over the length used, so far as ordinary micrometer measurements showed. Its linear mass was 7.585 gm/cm., as a mean of three determinations in close agreement.

The length of wire in the vibrating segment can be varied between 3 cm. and 60 cm., over a working range of from 250 to 2500 cycles per second.

A rectangular brass bar CD, Fig. 2, 60 cm. high, 2.5 cm. wide and .83 cm. thick, was graduated to a millimeter scale of length.

FIG. 1.



This vertical bar is supported on a flat circular brass base plate, 6.4 mm. thick and 250 mm. in diameter. This plate is, in turn, supported by three ordinary brass leveling screws, passing through projections at the edge of the plate. The bar is soldered to a small brass disk, 6.4 mm. thick and 55 mm. in diameter, which is fastened by screws to the base plate. The base plate also supports the vertical brass rod, which serves to carry the operating telephone T, mounted in a wooden frame at an adjustable height approximately half way between the bevel edges A and B. In practice, the height

of this telephone T does not have to be varied, and, in any future similar instrument, might be left fixed.

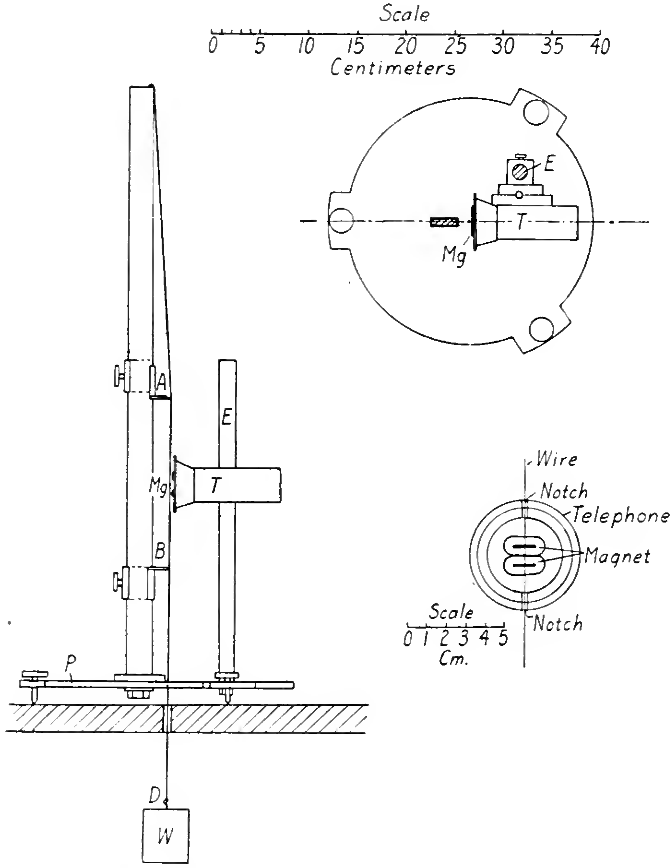
A rack and pinion screw, on the frame of the telephone T, enables the horizontal distance between the telephone poles and the vertical wire to be conveniently adjusted. The cover and diaphragm

FIG. 2.

of this telephone are removed. The metallic lip has a notch in it above and below, to permit the poles to approach the wire closely. The magnet of the telephone might be removed from its frame, as in the King sonometer, but the usual composition case affords a convenient mechanical protection. The poles should occupy the horizontal positions shown in Fig. 3, and no advantage has been found to attend any other position of these poles with respect to

the wire. The vertical steel wire tends to close the magnetic circuit of the telephone in the same manner as though it were a central strip cut from the ordinary diaphragm. At low frequencies, with long vibrating wire segments, the distance from poles to wire may

FIG. 3.



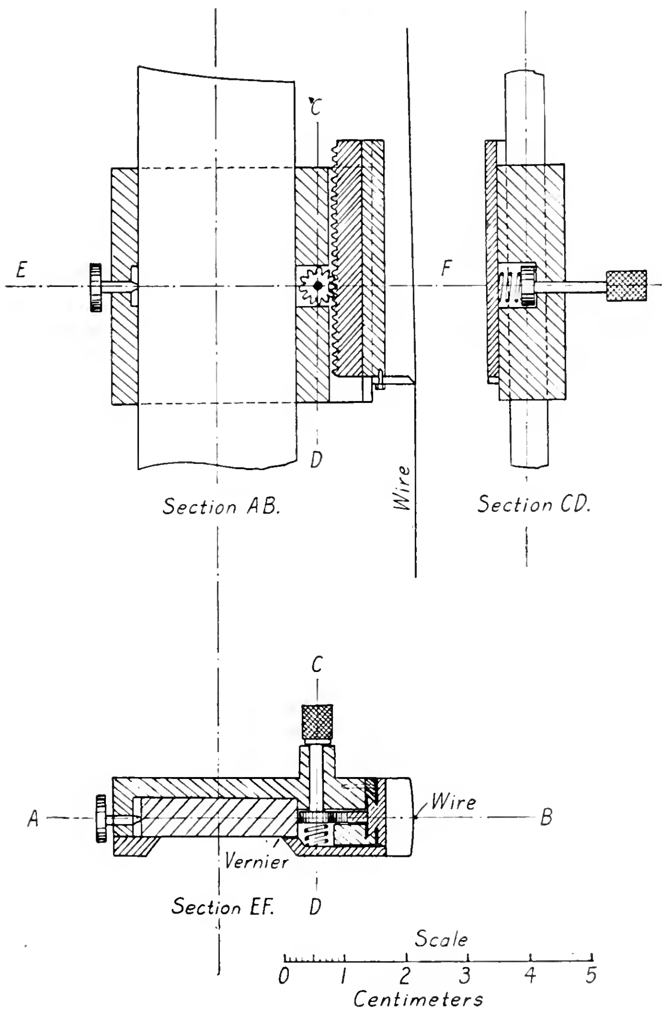
Mechanical measurement of the frequencies.

be 2.5 mm., to allow of free vibration; but at high frequencies, with short vibrating segments, the distance may be reduced to 0.5 mm., or less.

The lower brass bevel edge B has a simple sliding motion on the vertical bar, with a clamp screw to hold it in place. The upper brass edge A has, in addition to a clamp screw, a rack and pinion

vernier adjustment, as shown in Fig. 4. Final adjustments of the length to the vibrating wire segment are effected easily to a tenth

FIG. 4.



Details of the upper bevel edge.

millimeter at this vernier pinion screw. For convenience of reading the millimeter scale, the vertical rod has an arbitrary zero at a point about 20 cm. above the base. From this zero, the scale numbers

increase in each direction, so that the total length of the vibrating wire segment is always the numerical sum of the two bevel-edge readings. If this arrangement were not employed, the reading of the lower edge would have to be subtracted from that of the upper edge.

The steel wire is allowed to pass through a hole in the base plate, and also through a similar hole in the table. Beneath the table, the weight or weights W are suspended from the wire in the ordinary way. Fig. 3 gives drawings of the instrument in plan, and in side elevation.

METHOD OF USE.

The telephone T, Figs. 2 and 3, has its terminals connected to the source of alternating current to be tested. The particular telephone used has a direct-current resistance of 86 ohms and is a Western-Electric instrument of a standard type. At a frequency of 2000 ∽, an impressed e.m.f. of 5 volts rms. at telephone receiver terminals, produced a current of about 8.75 milliamperes, representing an impedance in the receiver of about 570 ohms.

In order to form an idea of the magnitude of the frequency to be measured, it is convenient to lay the diaphragm on the receiver, so as to hear the pitch of the sound emitted. This preliminary test also shows that the receiver is in operative condition. A rough estimate of the frequency can thus be made by ear. Reference to a calibration chart for the instrument will then show what distance between bevel edges AB may be looked for with a given suspended weight W. If the frequency is low, say below 500 ∽, the distance AB will be fairly large (at least 100 mm. with 900 gm.), and mechanical resonance is then easily detected as soon as the right distance AB is found, by the bowing of the wire into a ventral segment, as well as by its emitted sound. From the measured distance AB, and the applied weight W, the frequency can then be read from the calibration chart.

If the frequency to be measured is much above 500 ∽, the distance AB must be reduced. Thus at 2500 ∽, the distance AB becomes 52.5 mm. with a total weight of 5.4 kg. In such a case, the poles of the receiver T may have to be brought close up to the wire and the amplitude of resonant vibration is small. In a quiet room, the point of resonance can still be detected by sound, but the amplitude of vibration may escape notice, depending on the exci-

tation of the receiver. In a noisy room it may be necessary to use an auxiliary indicating device, and it is often convenient to use the latter, even under favorable conditions of measurement.

AUXILIARY DEVICE.

Various devices for indicating mechanical resonance have been tried. A very satisfactory device is found in a carbon microphone button, brought into contact with the wire below the bevel edge B, and therefore outside the principal vibrating segment. A unidirectional current of a few milliamperes is passed through the microphone button and a head telephone from a local 4-volt storage battery. In Fig. 2, however, an auxiliary hand telephone R is shown. The auxiliary receiver R reproduces in the ear of the observer, the tone of the exciting telephone receiver T. When mechanical resonance is attained, by securing the proper distance AB between bevel edges, the auxiliary telephone gives a clearly distinguishable loud tone; so that it is only necessary to separate the edges A and B slowly, starting both from their zero or coincidence position, to recognize resonance in the auxiliary receiver R. The microphone button is supported on the end of a flexible spiral spring, which, in turn, rests in a wooden block on the upright brass rod E. The contact between the button and the wire is normally so light that no appreciable change occurs therefrom in the tension of the wire.

CALIBRATION OF THE FREQUENCY-METER.

The instrument was calibrated in two ways, namely, (1) by measuring the rotary speed of the alternator supplying the telephonic frequency, (2) by measuring the frequency delivered to the telephone T with an electric bridge.

Fig. 5 shows an electrically driven stroboscopic fork,[1] mounted in front of a disk target carried by the rotor of the alternator diverting the frequency to be measured. The fork F can be adjusted in frequency, and in vibration, over a range of about 10 per cent., with the aid of the pulleys P and sliding weights S. This fork, in turn, had its calibration checked with the aid of speed

[1] "The Measurement of Rotary Speeds of Dynamo Machines by the Stroboscopic Fork" by A. E. Kennelly and S. Whiting, *Proc. A.I.E.E.*, June, 1908, p. 631.

counters. Fig. 6 is a calibration diagram, drawn on logarithm paper, with the frequency as ordinates, against the distance between bevel edges as abscissas, for five different values of the suspended weight. These give five parallel straight lines computed according to the formula

$$f = \frac{1798}{l} \sqrt{W} \qquad \text{cycles/sec.}$$

where l is the bevel-edge distance expressed in millimeters, and W is the suspended weight in grams. The actual calibration agreed substantially with these straight-line graphs, although the observations deviated occasionally to one side or the other. Higher frequencies and shorter bevel-edge distances call for heavier weights, while, on the contrary, the smaller weights should be used with the lower frequencies. Consequently, assuming that the proper weight is used, the frequency is read off the corresponding straight-line graph in Fig. 5.

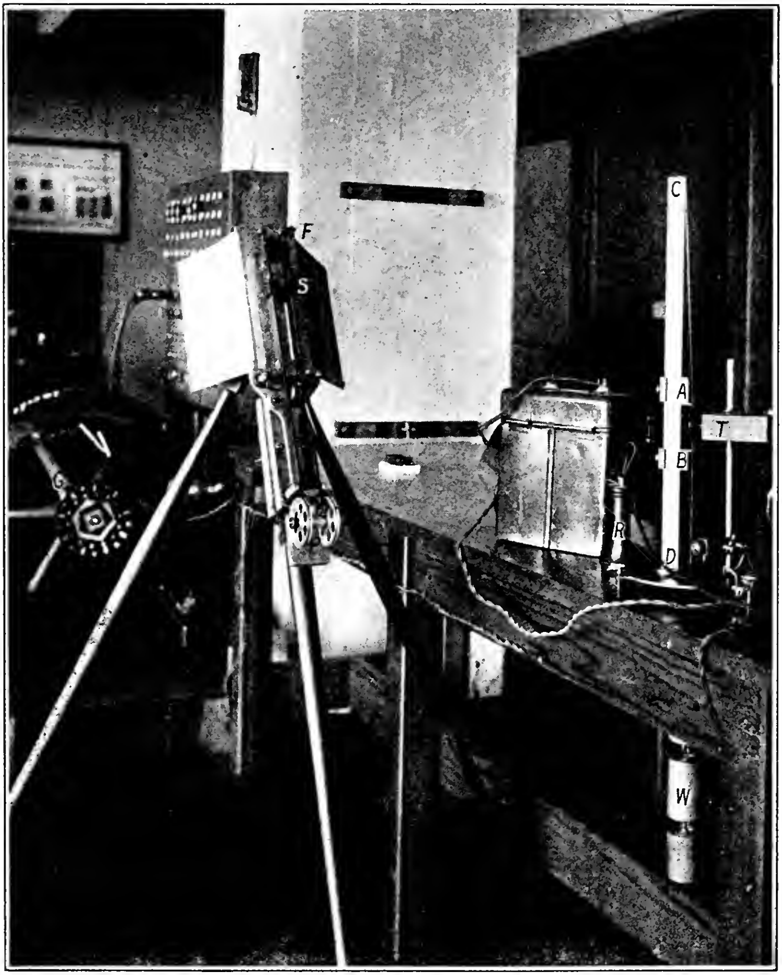
PRECISION.

The instrument is so sensitive to frequency, as was pointed out by Doctor King, that a bevel-edge setting can be adjusted and read ordinarily to one-tenth of a millimeter. If the bevel-edge distance was say, 10 cm., this would correspond to a nominal precision of 1 per mil. of the measured frequency. Owing, however, to certain errors in the instrument, the actual precision attainable has been distinctly less, and under favorable weight conditions, the actual deviation of a single observation was sometimes 1.5 per cent., or an error 15 times larger than that estimated by adjustment of length. It would appear that the error of observation, as that term is ordinarily understood, is small and rarely exceeds 2 or 3 per mil.; whereas systematic errors inherent in the construction used, attain 10 or 15 per mil. (1 to 1.5 per cent.), assuming that favorable weights are retained. If unsuitable weights are employed, the errors may be still greater.

It is supposed that the systematic errors here referred to are due to deviations of the actual nodal point from the bevel edges. In other words, if the vibrating wire formed its nodal points exactly at the bevel edges, these systematic errors might vanish. Further experimental investigation might advantageously be

directed toward eliminating these systematic errors, so as to increase the available precision.

FIG. 5.



ADVANTAGES OF THE INSTRUMENT.

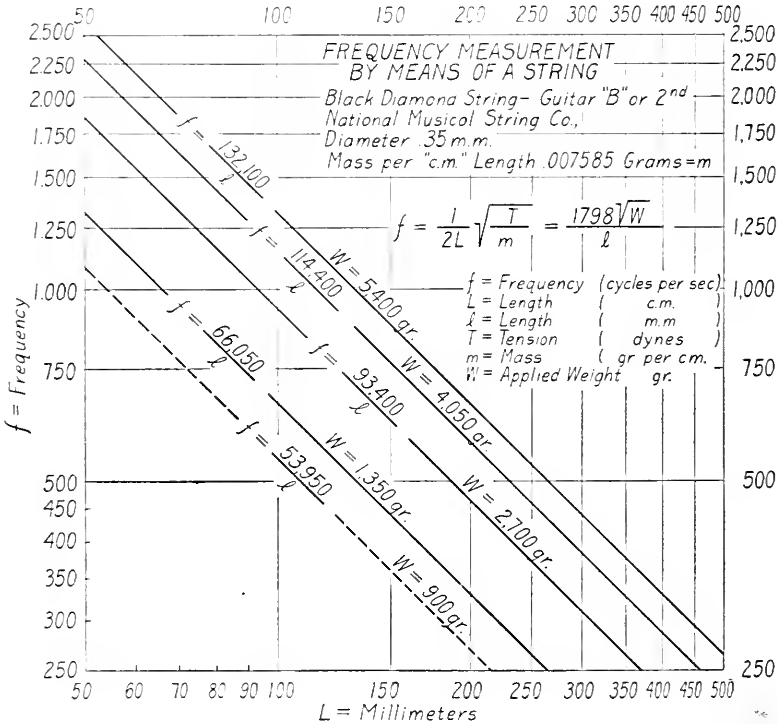
(1) The instrument is easily constructed. Although the form described is not very portable, it is well adapted to telephone laboratory use, and is not likely to get out of order.

(2) The instrument enables a frequency measurement to be made very swiftly.

(3) Very small power is consumed.

(4) It has been shown experimentally that the measurements are but little affected by wave shape of the current whose frequency is determined.

Fig. 6.



(5) Large available frequency range. The instrument here described covers a tenfold range.

DISADVANTAGES.

(1) Owing to the numerous possible nodes of vibration of a monochord, care must be exercised to measure the fundamental frequency, and not to be misled by mechanical overtones.

(2) Proper weights should be used with the instrument, in

accordance with the frequency to be measured. In the instrument described the recommended weights are as follows:

Frequency Cycles per second	Best weight Grammes
250 to 500	900
500 to 750	1350
750 to 1250	2700
1250 to 1750	4050

In the calibration of any particular instrument of this type, the best weights to use can readily be determined experimentally.

The authors desire to acknowledge their indebtedness, not only to Prof. L. V. King for the original idea of the instrument, but also to Prof. V. Bush, and to Prof. F. S. Dellenbaugh of our department, for help and valuable suggestions.

Death of Lippmann.—J. F. Gabriel Lippmann, the inventor of the Lippmann process of color photography, died in July last. He was born in 1845, in Luxembourg, of Alsatian-Lorraine parents, but went early to France, where he was educated and where his scientific work was all carried out. He received many honors, the greatest being the award of a Nobel prize in physics in 1918. His first scientific contribution was an essay on electro-capillarity, submitted as a thesis for the degree of Doctor of Sciences. In 1886 he was elected a member of the Academy of Sciences and numerous other appointments of trust and research were later given to him. The first notice of his remarkable procedure for obtaining color photographs by the interference method was made to the Academy in February, 1891, when he exhibited a photograph of a spectrum in its true colors. The paper appears on *C.r.*, 1891, v. 112, 274. In 1892 the French Photographic Society awarded him the Jannsen medal, and in 1897, the " Progress " medal was bestowed by the Royal Society of London. Lippmann's interest in photography continued through life and among his later contributions is one on the use of color screens in orthochromatic work.

The Lippmann process is simple in general principle but has never come into active use. It was not patented, and the inventor is said to have expressed regret that he did not at once take out patents, as he thought possibly this might have encouraged commercial exploitation. A recent issue of *La Revue Française de Photographie* gives the story of his life in some detail, and a brief account of the particular procedure upon which his fame principally rests.

H. L.

Dry Method for the Preparation of Lead Arsenate. O. W. BROWN, C. R. VORIS, and C. O. HENKE, of Indiana University (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 531–533), have devised a

method for the preparation of lead arsenate in the dry way. Lead monoxide (litharge) and arsenious oxide (white arsenic) are mixed in the proportion of 3 molecules of the former to 1 molecule of the latter. The mixture is roasted in a rotatory furnace; the optimum temperature for roasting is about 450° C. The two oxides combine to form lead arsenite, and this compound is oxidized to triplumbic arsenate $Pb_3(AsO_4)_2$. The oxidation at first is very rapid, then occurs very slowly. The amount of water-soluble arsenic in the product depends on the time and the temperature of roasting and on the relative proportions of the two oxides in the initial mixture. The process may be so regulated that the amount of water-soluble arsenic in the product is much less (approximately one-third) than that present in lead arsenate manufactured by the wet process.

J. S. H.

Influence of the Moisture Content Upon the Deterioration of Raw-dried Vegetables During Common Storage. H. C. GORE and C. E. MANGELS (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 523–524) have studied the influence of the moisture content of raw-dried or dehydrated vegetables upon their deterioration during the storage in air-tight containers at ordinary temperatures. The moisture content of the dehydrated product must not exceed the following values on entering storage if the distinctive color and flavor are to be well retained for 6 or more months: Carrots 4.99 to 7.39 per cent., turnips 5.00 per cent., onions 5.74 to 6.64 per cent., spinach 3.81 to 5.38 per cent., cabbage 3.00 to 3.34 per cent.

J. S. H.

Natural Indigo.—The culture of the indigo plant and the manufacture of indigo from it are described by W. R. G. Atkins (*Science Progress,* 1921, xvi, 56–70). The plants are cut and steeped in water at a temperature of at least 90° F.; a bacterial fermentation occurs, and the indican of the plant tissues passes into solution, and is converted into indoxyol. The resulting aqueous extract is beaten; the indoxyol is oxidizd to indigotin or indigo blue, which usually precipitates. If the supernatant liquid has a green color as the result of abnormal fermentation, the indigo in it is precipitated by addition of a small amount of dhak gum, and the yield is thereby increased. The indigo passes through processes of boiling, filtering, and drying. Natural indigo usually occurs in commerce as a cake with an indigotin content ranging from less than 50 per cent. to 70 per cent.; it is also being placed on the market as a paste. Synthetic indigo may ultimately displace the natural product as an article of commerce, However, the present high prices of raw materials, coal, and labor make the price of synthetic indigo so high that the production of natural indigo promises to be profitable for many years to come.

J. S. H.

PRESENTATION OF THE FRANKLIN MEDAL, AND CERTIFICATES OF HONORARY MEMBERSHIP, MAY 18, 1921.

At the Stated Meeting of the Committee on Science and the Arts, held January 5, 1921, the following resolutions were adopted:

"*Resolved*, That The Franklin Medal be awarded to Professor Charles Fabry, of the University of Marseilles, France, in recognition of his numerous and highly important contributions in the field of physical science, particularly the solution of optical and spectroscopical problems of fundamental importance."

"*Resolved*, That The Franklin Medal be awarded to Frank J. Sprague, of New York, New York, in recognition of his many and fundamentally important inventions and achievements in the field of electrical engineering, notably his contributions to the development of the electric motor and its application to industrial purposes, and in the art of electric traction, signally important in forming the basis of world-wide industries and promoting human welfare."

CORRESPONDENCE WITH MEDALISTS.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY JANUARY 11, 1921.

Professor Charles Fabry,
1 rue Clapier,
Marseilles, France.

SIR:

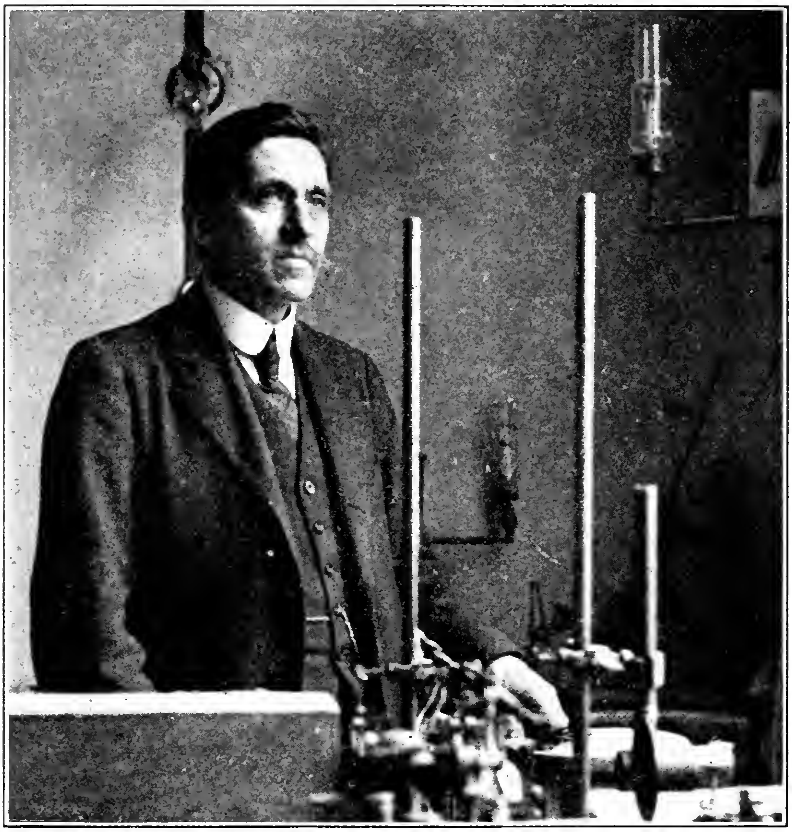
I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science and technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Professor Charles Fabry, of the University of Marseilles, France, in recognition of his numerous and highly important contributions in the field of physical science, particularly the solution of optical and spectroscopical problems of fundamental importance."

The medal and accompanying certificate are being prepared, and Mr. J. J. Jusserand, your Government's Ambassador at Washington, is being requested to come to the Institute on the afternoon of Wednesday, May 18th, to receive this medal and certificate on behalf of his Government for you.

I am,
Respectfully,
(Signed) R. B. OWENS,
Secretary.

RBO:H



Ch Fabry

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY

JANUARY 11, 1921.

Mr. Frank J. Sprague,
165 Broadway, New York City.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science and technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

"That The Franklin Medal be awarded to Frank J. Sprague, of New York, New York, in recognition of his many and fundamentally important inventions and achievements in the field of electrical engineering, notably his contributions to the development of the electric motor and its application to industrial purposes, and in the art of electric traction, signally important in forming the basis of world-wide industries and promoting human welfare."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon ot Wednesday, May 18th, to receive this medal and certificate from our President, Dr. Walton Clark.

I am,
Respectfully,
(Signed) R. B. OWENS,
Secretary.

RBO:H

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY

JANUARY 11, 1921.

M. J. J. Jusserand, Ambassador Extraordinary
and Plenipotentiary, Republic of France,
French Embassy, Washington, D.C.

SIR:

I have the honour to inform you that The Franklin Institute has awarded to Professor Charles Fabry, 1 rue Clapier, Marseilles, France, The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

"That The Franklin Medal be awarded to Professor Charles Fabry, of the University of Marseilles, France, in recognition of his numerous and highly important contributions in the field of physical

science, particularly the solution of optical and spectroscopical problems of fundamental importance."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on Wednesday, May 18th, to receive this medal and certificate from our President for Professor Fabry.

Two Franklin Medals have been awarded this year, one to Professor Fabry and one to Mr. Frank J. Sprague, Engineer and Inventor, of New York City, U.S.A.

An invitation will be extended to you and to Mr. Sprague to be the guests of honour at a dinner following the presentation ceremonies. This invitation will be formally sent you at a later date by the President of the Institute, Dr. Walton Clark.

I am,

Your Excellency's humble servant,

(Signed) R. B. OWENS,

Secretary.

RBO:H

FRANK J. SPRAGUE
165 Broadway
New York

JANUARY 18, 1921.

DR. R. B. OWENS, *Secretary,*
The Franklin Institute,
Philadelphia, Pa.

DEAR DR. OWENS:

I beg to acknowledge your letter of Jan. 11th, conveying official information that The Franklin Institute has awarded me "The Franklin Medal," and stating the grounds on which the award has been made, as well as inviting me to be present to receive it on the 18th of May.

I shall be glad to accept this invitation and to then formally express, as I do now also, my appreciation of the gratifying recognition of my work by the bestowing of this great honor.

I am deeply sensible of the fact that there are many who are in the highest degree deserving of recognition by the Institute and that in thus being singled out for distinction I am specially indebted to those on whom the responsibility falls for selection.

Pray accept for yourself my personal thanks, and likewise my deep sympathy and concern over the report that you are temporarily prevented from active participation in your duties as Secretary, with the hope of your early complete recovery.

Sincerely yours,

(Signed) FRANK J. SPRAGUE.

AMBASSADE
DE LA RÉPUBLIQUE FRANÇAISE
AUX ETATS-UNIS

WASHINGTON, le January 24, 1921.

DEAR SIR:

I beg to acknowledge receipt of your letter of the 11th, and to express the feeling of gratification with which I learnt of the bestowal of The Franklin Medal on my compatriot, Professor Charles Fabry.

I cannot, owing to my duties here, pledge myself in advance to go to Philadelphia on May 18th, to receive in person the medal and the accompanying certificate. In case I am prevented, I would appoint, if agreeable to you, a representative to act in my stead.

Believe me, with best regards,

Sincerely yours,

(Signed) JUSSERAND.

MR. R. B. OWENS, *Secretary,*
The Franklin Institute,
Philadelphia, Pa.

FACULTÉ DES SCIENCES
PARIS
PHYSIQUE
LABORATOIRE D'ENSEIGNEMENT
1, rue Victor-Cousin (5e Arr.).

PARIS, le 30 Janvier, 1921.

MY DEAR DR. OWENS:

I received yesterday your letter, coming via Marseille, informing me of the award to me of The Franklin Medal. I appreciate deeply the honour done me by The Franklin Institute. The list of medalists includes the names of scientists of world-wide prominence, and I am very proud to be placed among them by the Institute. Moreover, the medal will be for me a recollection of a visit to America in war time, and will recall to me the gratefulness that every Frenchman owes to your country.

Two weeks ago I was appointed a professor at the University of Paris (Sorbonne), and am already at work in my new laboratory.

It is not without sorrow that I left my laboratory at Marseille, in which I worked for so long a time, but my colleagues in Paris insisted so strongly upon my coming to them that I felt it necessary to accept.

I hope my new position will give more opportunity to meet my American friends.

Very sincerely yours,

(Signed) CHARLES FABRY.

UNIVERSITÉ DE PARIS
FACULTÉ DES SCIENCES
PHYSIQUE
LABORATOIRE D'ENSEIGNEMENT
1, rue Victor-Cousin (5e arr.).

PARIS, 10 APRIL, 1921.

CHER DR. OWENS:

C'est un grand honneur pour moi d'étre placé sur la liste des members honorare de l'Institut Franklin. Veuillez exprimer mes cordiaux remerciements au President et aux members de l'Institut, sans oublier vous-même.

J'éspere que vous avez reçu le manuscript de mon "paper," que je vous ai envoyé de Marseille il y a environ deux semaines. Je regrette beaucoup de ne pouvoir le lire moi-même à votre réunion de mai; mais la lecture sera beaucoup plus agréable si elle est fait par mon ami Ames. Veuillez le remercier pour la peine qu'il se donne à cette occasion.

Nous avous le plaisir, en ce moment d'avoir à Paris notre illustre compatriote Michelson, qu'est venu dans notre Universite comme "exchange Professor." Les leçons sont un grande succès.

Je suis particulièrement heureux des bonnes nouvelles que vous me donnez de notre vue. La nécessité de porter des verres n'est nullement génante; voilà longtemps que je ne peux pas lire autrement et que j'ai pris l'habitude de considerer mes verres comme faisant partie de ma personne, comme mes bras ou mes jambes.

Le text de la "minute" est très bien, excepte qu'il est beaucoup trop èlogieux pour mes travaux.

Cordialement à vous,
CH. FABRY.

CONFERRING OF HONORARY MEMBERSHIP.

AT the Stated Meeting of The Franklin Institute, held March 16, 1921, the following resolution was adopted:

> "*Resolved*, That General John J. Pershing be elected an Honorary Member of The Franklin Institute, in recogniton of his signal success in the use of scientific and technical methods and means in modern warfare."

CORRESPONDENCE.

MARCH 17, 1921.

General John J. Pershing,
General of the Armies of the United States,
War Department, Washington, D. C.

SIR:

I have the honour to advise you that at a regular meeting of the Institute, held on the evening of Wednesday, March 16th, the following resolution was unanimously adopted:

"*Resolved*, That General John J. Pershing be elected an Honorary Member of The Franklin Institute, in recognition of his signal success in the use of scientific and technical methods and means in modern warfare."

It is hoped that it may be possible and agreeable to you to be at our May meeting to be held on the afternoon of Wednesday, May 18th, and receive from our President an engrossed copy of the Institute's action.

I am,

Your very obedient servant,

(Signed) R. B. OWENS,

RBO:H *Secretary*.

GENERAL OF THE ARMIES
Washington

MARCH 21, 1921.

Dr. R. B. Owens, Secretary,
The Franklin Institute,
Philadelphia, Pennsylvania.

MY DEAR DOCTOR OWENS:

I am deeply gratified at the action of The Franklin Institute on March 16th in electing me to honorary membership, and I am very proud to accept this mark of distinction at their hands. I hope you will convey to the officials of the Institute my deep appreciation of this honor and my hearty thanks for their courtesy.

It is not possible for me to say at this time whether I can attend the meeting on the afternoon of May 18th, but if my plans will permit, I shall be very happy to do so.

With assurances of my high regard,

Very Sincerely yours,

(Signed) JOHN J. PERSHING.

PROGRAMME OF MEETING, MAY 18, 1921.

Presentation of Certificate of Honorary Membership to General John J. Pershing, General of the Armies of the United States.

Presentation of the Franklin Medal and Certificate of Honorary Membership to His Excellency, M. Jusserand, French Ambassador, on behalf of his Government, for Professor Charles Fabry, the University of Paris, Paris, France.

Presentation of The Franklin Medal and Certificate of Honorary Membership to Frank J. Sprague, New York City.

Papers:

"Studies in the Field of Light Radiation." By Charles Fabry, D.Sc. Read by Joseph S. Ames, Ph.D., LL.D., The Johns Hopkins University, Baltimore, Maryland.

"Electric Traction—A Review." By Frank J. Sprague.

PRESENTATION OF THE FRANKLIN MEDAL AND CERTIFICATE OF HONORARY MEMBERSHIP TO PROFESSOR CHARLES FABRY AND MR. FRANK J. SPRAGUE, AND CERTIFICATE OF HONORARY MEMBERSHIP TO GENERAL JOHN J. PERSHING.

IN calling the meeting to order Mr. Coleman Sellers, Jr., Vice-President of the Institute, said:

I greatly regret that severe illness will prevent our President, Dr. Walton Clark, from being with us this afternoon. Doctor Clark has taken the greatest interest in this meeting and I am sure that his inability to be present is as great a disappointment to him as it is to us.

This is a regular stated monthly meeting of the Institute, held at an unusual hour, for the greater convenience of some of our distinguished guests.

As this meeting is dedicated to a particular purpose, the usual order of business will be dispensed with.

The special business of this meeting will be the presentation of the Franklin Medals which have been awarded to Dr. Charles Fabry, of Paris, and to Mr. Frank J. Sprague, of New York City.

A further object of this meeting will be to formally testify our appreciation of the character, attainments and services of John J. Pershing, General of the Armies of the United States, recently appointed by the President as Chief of the General Staff of the Army.

The Chairman then recognized Dr. Harry F. Keller, who introduced General Pershing as follows:

Mr. President: At a stated meeting of the Institute held on the evening of Wednesday, March 16, 1921, the following resolution was unanimously adopted:

> *Resolved,* That General John J. Pershing, General of the Armies of the United States, be elected to Honorary Membership in the Institute, in recognition of his signal success in the use of scientific and technical methods and means in modern warfare.

I have the honour to present to you General Pershing.

The Chairman in presenting the Certificate of Honorary Membership said:

General Pershing: I have the honour in the name of The Franklin Institute, and upon the unanimous recommendation of

its Committee on Membership, the unanimous endorsement of its Board of Managers, and the unanimous vote of its stated meeting, to present to you a Certificate of Honorary Membership in The Franklin Institute of the State of Pennsylvania. The members of the Institute, remembering your brilliant services to our country and to mankind rendered on the fields of heroic France, realize that you honour the Institute in accepting this Certificate.

General Pershing, in accepting the Certificate of Honorary Membership, said:

Mr. Chairman, Ladies and Gentlemen: It would be very difficult for me to express clearly on this occasion my very deep appreciation of the honour that has been conferred upon me by this world-renowned Institute. Recognized, as it is, in the scientific world as a leader, I am doubly proud to become one of its members. All other things being equal, we know that which leads in science would naturally lead in war. The contributions made to the conduct of the war by scientific and technical men of America cannot be overestimated. The contributions made by the distinguished members of The Franklin Institute deserve especial consideration and praise at the hands of those who are in a position to know what their services were and the American people in general know that The Franklin Institute especially deserves credit for the number of its members who saw active service abroad, one in twelve of the membership of The Franklin Institute having served in the World War; eighty-four held commissions in the army, and I am glad to observe that fifty-five of them held positions in the army with the rank of field officer or higher, twenty-eight others were officers in the Navy, and fifty-nine were on active government service without military rank. More than twenty members were honoured for their service by the French, British, Belgian, Italian or American Government.

It is an especial pleasure to me, and one which I wish to state here to this gathering, to meet a very old-time friend of mine, your Secretary, Doctor Owens, and to have him to receive me on this occasion, bringing back as it does our service together some twenty-five years ago when we were both young men at the University of Nebraska.

I again express my very deep appreciation of the honour

you have conferred upon me by making me an Honorary Member of this illustrious Institute.

Dr. Joseph S. Ames, of the Johns Hopkins University, was then recognized and presented the following statement of the work of Professor Charles Fabry:

Mr. President: Your Committee on Science and the Arts in its recommendations for the award of the Franklin Medals has, in my judgment, shown rare wisdom and discrimination. The essential condition in the deed of gift is that the medals shall be bestowed upon those " whose efforts, in the opinion of the Institute, have done most to advance physical science or its applications." The first of these medals to be awarded to-day cannot, unfortunately, be placed in the hands of the recipient himself, as his duties in Paris make it impossible for him to be with us. But we are honoured by the presence of the official representative of the French Republic, who has graciously consented to accept, on behalf of his Government, The Franklin Medal for his fellow-countryman, Dr. Charles Fabry, Professor of Physics in the University of Paris. It is awarded him in recognition of his invaluable contributions to the science of spectroscopy.

Charles Fabry was born at Marseilles on June 11, 1867; and, after preliminary studies in his native city was admitted to the famous École Polytechnique in 1885, where he remained for three years. He then returned to Marseilles. In 1892, while a professor of physics at the Lycée of Bordeaux, he presented his thesis for the degree of Doctor of Physical Sciences to the Faculty of the Sciences of the Academy of Paris, and received his degree. Two years later he was appointed Professor at the University of Marseilles and during the present year has been called to the University of Paris.

Fabry's thesis bore the title—expressed in English—" Theory of the Visibility and Orientation of Interference Fringes " and was dedicated to Professor Macé de Lépinar, of the University of Marseilles. To this renowned physicist we owe a great debt for attracting the attention of his pupil to the important field of spectroscopy. The thesis is the extension of work previously done by Fabry and reported briefly in the Comptes Rendus of the Academy two years before. It deals with the most interesting subject of the localization in space of interference fringes, which

are seen in so many optical phenomena, and with which every one is familiar from the brilliant colors of soap-bubbles, of thin layers of oil or gasoline and of the opal. The memoir shows a happy combination of mathematical knowledge, of physical insight and of experimental ability; a combination most rare. It was the first of a long series of papers, all connected with spectroscopy, which have continued to the present time and which have delighted and inspired every student of Physics. His theoretical papers have never given us theories unsupported by experiment, but have always led us farther into actual knowledge of the constitution of matter; and his experimental investigations have been models of clearness of purpose and of technical ability.

The name Fabry is known to every elementary student of physics, even in his college days, from association with a new form of optical apparatus which bears the name Fabry-Perot interferometer, and which has contributed more than any other instrument to our knowledge of spectra. The results of modern spectroscopy rest entirely on its use. It was devised, in collaboration with M. Perot, in 1897, and furnishes us the means of measuring the wave-lengths of waves of light with the greatest accuracy, and of analyzing radiations to the degree required for most fundamental investigations. This same instrument, or the principle upon which it is based, also lent itself to an investigation made by Fabry and others, which may be said to be of "practical" importance. All engineering practice involves measurements of length; the universal standard is the meter-bar and its copies. Questions have arisen as to the permanence of this standard, as to whether the metallic bars changed with time; and, in order to have a standard about which no such questions could be asked, it was proposed to measure the meter-bar by means of light-waves. This was first done by our American physicist, Professor Michelson, and later by Fabry, Perot and Benoit. Their results, published in 1913, have once for all determined our standard of length.

In the field of pure science Fabry applied his instrument to the two essential questions of spectroscopy: Accurate measurement of wave-lengths and the investigation of the sources of radiation. This last investigation was in part theoretical, and it has led to a most important relation between the molecular weight of a gas and the character of its radiation. In short, there

is no detail in all the vast domain of spectroscopy which he has not studied and with reference to which he has not notably increased our knowledge. Within recent years his work has dealt with photometry, the science concerned with the intensity of radiation as distinct from its analysis; and here too his contributions to our knowledge and our technique are most valuable.

It was but natural that, when France was plunged into the Great War which threatened her existence and our whole civilization, Fabry should have been called to serve his country in that field in which he was preëminent, the design of apparatus and invention of scientific methods. His work for the Ministry of Inventions was extraordinarily useful, and was so recognized. When, in the early summer of 1917 it was decided to send a mission of scientists to America to help us in our preparation for the war and to acquaint our military authorities with recent technical developments, Fabry was selected to be its leader, and, as Major Fabry, he came to this country in June of that year. Only those familiar with the actual facts can realize the value of the services of this Mission, and one of the outstanding causes of its success was the personality of its chief. It was not his first visit to this country. He knew us and our ways. He possessed all the scientific and technical knowledge required; he was modest, tactful and absolutely without thought of self; but, more important still, he has a sense of humor and an appreciation of our own American variety. He made friends of all, he inspired absolute confidence, and his influence was felt in every detail of our scientific work in the war.

It is particularly fitting that Fabry should be awarded a Medal bearing the name of Franklin. The latter by his visit to France interpreted America to the French people; he presented to them the ideals and the purposes of Americans; it is believed that he was personally liked by the French. So it is with Fabry to-day. He is loved by all Americans who know him, and to every one he is the representative of all that is best and highest in French science. France owes a great deal to him, for he is in every way a worthy son, and our appreciation of French scientific ideals and investigations is exhalted on account of him.

I only wish that you could have the pleasure of seeing him in person to-day. A few of us who have known him for many years have him clearly in our minds. We hear his deep sonorous

voice and his merry laughter; we see his clear, inspiring, sympathetic eyes; we stand under the charm of a great scientist and a true Frenchman. Surely the Midi, the province of his birth, endowed him with those qualities which endear him most to us.

In his absence, however, Mr. President, The Franklin Medal awarded him will be accepted on behalf of his government by His Excellency M. Jusserand, the Ambassador of the French Republic, whom I have the honour to present to you.

The Chairman then said:

Ambassador Jusserand: Permit me, Sir, to assure you that the members of The Franklin Institute realize fully the high distinction which is conferred upon their meeting by the presence this afternoon of the Official Representative of France, our great and greatly beloved Sister Republic.

Your Excellency, The Franklin Institute, upon the recommendation of its Committee on Science and the Arts, has awarded to your countryman, Professor Charles Fabry, The Franklin Medal. This is granted to Professor Fabry in recognition of his distinguished services to mankind rendered in the field of Science. I have the honour, Your Excellency, in the name of the Institute, to hand you The Franklin Medal and Diploma, and a Certificate of Honorary Membership in The Franklin Institute of the State of Pennsylvania, with the request that you transmit them through your government to Professor Charles Fabry, the medalist. You may assure him that this award is the highest honour in the gift of the Institute.

M. Jusserand, in accepting the Medal and Diploma and the Certificate of Honorary Membership, said:

Mr. Chairman, Ladies and Gentlemen: It is with heartfelt appreciation that I accept on behalf of the French Government for Professor Charles Fabry this Medal and the Diplomas which accompany it. They will be duly forwarded and my Government will be informed of what has just taken place, and I hope that there shall be another to add to these honors, one which will not be less appreciated, that is the text of the tribute we have just heard paid Professor Fabry by Doctor Ames. It is so illuminating and so deserving of praise that I am sure that when Professor Fabry has read it he will measure its value with that of the Medal and Honorary Membership in this Institute. I know it will be

a great pleasure for him to think that these honors are bestowed by an Institution bearing the name of the first Minister sent by your country to France, a Minister possessed of the highest combination of scientific and diplomatic attainments.

In reading the works of Franklin there is hardly a page on which we do not find something relating to physical science. Of all the world's great physicists, few have possessed keener critical faculties, greater vision, or a more highly trained imagination. His work in the field of electricity was perhaps the most notable. His discovery of the electrical nature of lightning discharges alone would have made him famous.

While acknowledging the tributes this Institution is paying to Professor Fabry, it is a pleasure to me to note the many honors now being conferred upon his and my fellow countrywoman, Madam Curie, by other great Institutions of learning in America. Her discovery of radium was epoch-making in physical science. Not only has there resulted from this discovery an amazing fund of knowledge relating to the constitution of matter, but in the hands of the physician radium is serving to alleviate and in many cases cure one of the most painful of human maladies. What further secrets the elements may hold and the physicists reveal cannot be foreseen, but it is certain that there are secrets and that they are discoverable only by the scientist possessed of vision and highly trained imagination.

I read with interest in your Journal of last year a paper by Professor Svante Arrhenius on "The World's Supply of Energy." If you have also done so, you will appreciate that the world's coal and petroleum supplies are limited and that eventually other sources of energy must be utilized or discovered if modern industrial civilization is to continue. Among the great forces of nature which we have not yet to any considerable extent harnessed are those of the winds and the tides. Wind power, while great at places and at times, is so inconstant as to be non-commercial; but the utilization of tidal power offers greater promise of success.

I am glad to tell you that a number of favorable situations exist along the French seacoast for the development of the power of the ocean's tides. A remarkable natural site exists in the vicinity of Minihic-St.Suliac, where it is probable that some 40,000 kw. may be continuously produced on a commercial basis.

With the utilization of the power of falling waters and ocean

tides to their fullest much may be done to lessen the demand on the world's coal and oil fields as sources of power. However, should the power from water, coal and oil fail ultimately to meet the needs of industrial civilization, the physicist still holds for us another hope, namely, that of freeing the internal energy of the atom on a commercial scale. Who can predict how soon this may be done?

Mr. W. C. L. Eglin was then recognized and made the following statement concerning the work of Mr. Frank J. Sprague.

Mr. President, Members of The Franklin Institute, and Guests: I have the honour to present Mr. Frank Julian Sprague, to whom, upon the recommendation of the Institute's Committee on Science and the Arts, has been awarded The Franklin Medal, in recognition of his many and fundamentally important inventions and achievements in the field of electrical engineering.

Mr. Sprague was born at Milford, Connecticut, July 25, 1857. He won a competitive appointment to the United States Naval Academy, and was graduated therefrom in 1877. Almost from the time he entered the Naval Academy until he resigned from the naval service, he was especially interested in electrical studies; and during this time he conducted a number of experiments and investigations of applications of electricity in the Navy. His notebooks of that period contain many outlines of inventions which have since been developed and are now applied on naval vessels. He was thrown in contact with the leading scientists and electrical engineers of the world by acting as secretary of a jury composed of eminent scientists at the British Electrical Exhibition held in Sydenham, England, in 1882.

Upon the completion of this work, Mr. Sprague decided to associate himself with Mr. Thomas A. Edison and engage in the development of improvements relating to the electric light distribution system.

About this time, Mr. Sprague conceived the idea of the importance of the developments that were possible by means of the electric motor, and he withdrew from Mr. Edison and organized the Sprague Electric Railway and Motor Company. He succeeded in developing one of the first practical electric motors which was available for all kinds of industrial purposes. His notable work in 1887 for the Union Passenger Railway Company

of Richmond marked the first successful electric street railway system. In this undertaking, Mr. Sprague designed the first complete system including the power house, the transmission and distribution system, and the electrical equipment on the cars; which later became the standard practice for street-car equipment throughout the world. There were many features of fundamental importance in this early development, notably the method of mounting the motor on the axle and the spring suspension between the trucks, which insured the proper alignment between the driving shaft of the motor and the driven wheels; the light trolley wire reinforced by feeders, and the under-running trolley. The work at Richmond provided the necessary information for the solution of the urban street-car transportation problem.

Mr. Sprague, however, continued his work on other inventions and developments of apparatus, and devised means for the electrical operation of both elevated and subway trains through a system known as "multiple-unit control," whereby a master controller is capable of operating any number of cars either with or without motor equipment, in the form of a continuous train, with a single operator, this system being equally applicable to two or more locomotives.

Mr. Sprague has been a pioneer in the invention and development of transportation for both freight and passengers, for all classes of railroad service, and to him is due the great development which has been made in the progress of the art.

The work of Mr. Sprague in connection with street railways and elevated and underground railroads naturally turned his attention to the electrical operation of elevators, and here again his marked inventive and constructive ability made possible the electric elevator which is now almost universally used for both passenger and freight purposes.

The development of the electric motor and its application to industrial purposes and in the art of electric traction, have done much to increase the establishing of world-wide industries and have greatly helped in promoting human welfare. Mr. Sprague has had the good fortune to live to see his discoveries and inventions applied to this art of electric traction throughout the world.

The Institute in 1903 awarded to Mr. Sprague the Elliott Cresson Medal, and now we are happy to be able to present him to you for the award of The Franklin Medal and the accompanying

Certificate, and the Certificate of Honorary Membership in the Institute—the highest honours it can bestow.

The Chairman, in presenting The Franklin Medal and Diploma and Certificate of Honorary Membership to Mr. Sprague, said:

Mr. Sprague: I have the honour in the name of The Franklin Institute and on the recommendation of its Committee on Science and the Arts and in recognition of your distinguished services to mankind rendered in the field of applied science, to present to you The Franklin Medal and Diploma, with a Certificate of Honorary Membership in The Franklin Institute of the State of Pennsylvania.

This is the highest honour in the gift of the Institute.

Mr. Sprague, in accepting the Franklin Medal and Diploma and the Certificate of Honorary Membership, said:

Mr. Chairman, Members and Guests: I would not be quite human if, on an occasion of this kind, when receiving from the oldest and most dignified scientific institution of this country so notable a mark of its consideration, in the award of the medal bearing the name of the great Franklin and the adding of my name to the illustrious list carried on your Honorary roll, I did not feel both a sense of pride and humility—especially as my work has been less that of the physicist than of one who has endeavored to make use of the fundamental facts discovered by patient delvers into the mysteries of the physical world.

Mr. Eglin in his kind references to me has betrayed my age, perhaps as an evidence of many years of work, but I feel somewhat solaced by the fact that, in the presence of the Ambassador of that country for which we have so close a friendship and of the General who was at the head of our armies operating there during the late war, a like award is also extended to Professor Fabry, a distinguished son of France and one of the greatest living scientists. It has made me feel that the ties between our countries are even more closely knit.

I cannot regard this honour entirely as an individual one, but to a great degree as one granted also to those who have been associated with me and with the development of electric art, so many of whom have had no personal recognition. Fortunately for me I have lived to receive such.

In every specific advance of human endeavor it is at least convenient, and customary, to choose some name as a sort of reference mark, the work of such a one being something like a hub around which other perhaps equally important work revolves, and it is, of course, a matter of great personal satisfaction that mine has been considered of sufficient importance to merit this distinction.

As an ex-Naval officer, I am glad also for my alma mater, the U. S. Naval Academy, and I wish to take this opportunity to say that I am one of those who believe that our schools, colleges and universities, however much they sometimes may be criticized, are the institutions which, because of their laying of the basis of mental training, largely make the men of the country. A few years ago an engineer of a great manufacturing company, in addressing his brother engineers at Manchester, England, in reply to the query as to what in his opinion was the most important influence in the development of the electric art, replied in effect that while his first answer would have been the discovery of three enumerated inventions he had come to the conclusion that it was the introduction of the University man into it.

As one surveys the great body of men now engaged in responsible fashion the force of this admission is evident, and as a testimonial to the importance of proper technical training it is important to note that it is with great difficulty that a young man without a University training can enter even the student courses of the more important electrical corporations.

When I look at this medal I am wondering whether it is after all quite real, as we of past generations understand realities, for because one of our sister planets has exhibited slight vagaries in her annual peregrinations, and possibly for some other reasons which I do not understand, our old friends Newton and Euclid seem no longer secure on their pedestals, for we are informed by a distinguished mathematician that three dimension measurements must now be corrected by a time element.

According to this new, and to my practically inclined mind somewhat abstruse theory, this medal when I move it from me outwards changes its dimensions somewhat. But on consideration I must after all consider it a very real thing, because I call to mind the fact that unless it is moved with a velocity approaching that of the maximum thus far observed and reputed impos-

sible of increase, the speed of light, the fourth dimension represented by the time element, is of no particular importance.

Possibly it indeed may be found that there is not much new even in the electrical field after our friends of the American Philosophical Society have finished deciphering the strange hieroglyphics of a famous monk of the early centuries, one Roger Bacon. It is strange how the name of Bacon arises to trouble us, first as one through whom the authorship of our greatest dramatic writings is assailed, and now of another who may be found to have antedated so much of modern discovery.

However, I shall not allow myself to be disturbed by these scientific and historical possibilities, but cling with such tenacity as I may to this evidence of present honour, for which I again deeply express my thanks.

Dr. Joseph S. Ames then read the paper on "Studies in the Field of Light Radiations," prepared by Professor Charles Fabry for the occasion, and Mr. Sprague presented a paper on "Electric Traction—A Review." [1]

The Second Royal Society Conversazione for 1921. (*Nature*, June 2, 1921.)—Sir John Dewrance and Prof. E. G. Coker exhibited an arrangement for investigating the stresses arising from the use of turning tools. Both tool and work were made of transparent material and polarized light was transmitted through them. From the effect produced upon the light the stresses could be derived.

The Meteorological Office had on exhibition an apparatus for recording atmospheric pollution. Every 15 minutes two litres of air are drawn through a piece of blotting paper. From the darkness of the deposit is inferred the amount of suspended matter. Records showed the reduction owing to the coal strike. A close connection was shown between the vertical electrical force and the amount of suspended matter.

From the National Physical Laboratory came a Paterson-Walsh electrical height finder by which is obtained a continuous indication of the height of air craft.

The Science Museum showed an Eötvös gravity torsion balance for investigating the variation of gravity over small distances. This has been employed in Hungary for locating deposits of ore whose density differs considerably from that of its surroundings.

G. F. S.

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[1] These papers appear on pages 277 and 291, respectively, of this issue.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A PORTABLE VACUUM THERMOPILE.[1]

[ABSTRACT.]

A DESCRIPTION is given of a portable vacuum thermopile, of glass, in which a calcium evacuator is permanently attached to the container. The paper gives general directions for operating the device, as well as data on the thermopile, which is of bismuth-silver.

Observations extending over a period of about seven years are given on the behavior of vacuum thermopiles in which the vacuum is maintained by means of calcium, which has the property of combining with gases when it is heated.

INTERFERENCE MEASUREMENTS IN THE SPECTRA OF ARGON, KRYPTON, AND XENON.[2]

By F. W. Meggers.

[ABSTRACT.]

THE spectra of the inert gases, especially of the heavier ones, contain strong lines which represent wave-lengths possessing a high degree of homogeneity and reproductibility and these lines are therefore suitable for use as standards of wave-length. This paper gives the values of 50 wave-lengths in the spectrum of argon (3948 to 8521 A), 18 of krypton (4273 to 7601 A) and 12 of xenon (4500 to 4923 A), all of which have been compared with the wave-length of the red radiation from cadmium (6438.4696 A) which is the international primary standard. These wave-length comparisons were made by means of etalon-interferometers and most of the values are probably correct to one part in several millions. The elegance and precision of the interferometer methods for wave-length comparisons demonstrated by the close agreement between values obtained by different observers, and also by the constant

* Communicated by the Director.

[1] Scientific Paper No. 413.

[2] Scientific Paper No. 414.

frequency differences of many of the lines belonging to combination series. There are only a few cases where independent observers differ by 0.004 A or more. From the wave-length measurements in argon and krypton, frequency differences are obtained which are constant within the probable error of the measurements. This further confirms the exactness of the Combination Principle of Ritz. If these frequency differences are regarded as true constants they testify to the accuracy in relative value of the wave-lengths involved.

A PRELIMINARY STUDY OF TEARING INSTRUMENTS AND TEARING TEST METHODS FOR PAPER TESTING.[3]

By Paul L. Houston.

[ABSTRACT.]

IN this technologic paper a study is made of the relative effect of different sizes of test samples on the tearing strength of paper. A great number of samples of commercial papers are torn on three different instruments, using different sizes of test samples and also the same sizes of test samples. Data are collected, accordingly, to show that the larger the test samples, the greater are the values of tearing strength. The reason for this is brought out as fabric assistance, which is of considerable importance in the textile industry.

The three instruments used in this study are a tensile strength instrument and two types of instruments for determining the tearing strength of paper. These two types of instruments are called type I and type II. Type I is a recording instrument, while type II is a non-recording instrument. A study is then made of these two types of tearing instruments for the purpose of investigating their accuracy and reliability, so that the results of this investigation may benefit the paper industry.

It is found in this study that it is impossible to calibrate the type I recording instrument because of the friction in the pin-slot bearing of the recording arm and the friction between recording pen and paper chart. Also, in a performance test the recording instrument does not check itself on the same grade of paper within the variation of the strength of the fibres themselves. On the other

[3] Technologic Paper No. 194.

hand, it is found that the type II non-recording instrument is accurate within 5 per cent. on the majority of papers, with the exception of those writings and printings that are of lighter weight than 50 lb. to the sandard size ream, $25 \times 40 - 500$. This instrument does also check itself in a performance test on the same grade of paper within the variation of the strength of the fibres themselves.

Conclusions are drawn up to show that the type I recording instrument is not an accurate and reliable piece of apparatus, and that the type II non-recording instrument is the more reliable of the two, and is sufficiently accurate and reliable for a mill test on the majority of papers, but not sufficiently accurate for a laboratory test.

Sour Salt.—CHARLES H. LA WALL (*Am. J. Pharmacy*, 1921, xciii, 496–497) states that "sour salt" is a synonym for tartaric and citric acids. These acids are sold under the name of sour salt as a condiment, and are used to reinforce vinegar in imparting acidity to certain foods. The "salt" always occurs in commerce in the crystalline form. It has been adulterated by substitution of alum crystals for a part or all of the organic acids. J. S. H.

Reaction between Sodium Carbonate and Chrome Alum.—According to LOUIS MEUNIER (*J. Amer. Leather Chemists' Asso.*, 1921, xvi, 321–327), chromic hydroxide is precipitated when sodium carbonate acts upon a cold, freshly prepared solution of chrome alum. The precipitate is a basic chromic sulphate when sodium carbonate acts upon a very old solution of chrome alum, or when precipitation occurs at a temperature of 100° C. The sodium carbonate neutralizes the sulphuric acid, which has been formed by hydrolysis of the alum in aqueous solution, and also coagulates the colloidal chromic hydroxide or basic sulphate which have been formed in the aqueous solution. J. S. H.

Potable Water and Its Hydrogen Ion Concentration.—For the determination of the hydrogen ion concentration of drinking water, J. M. KOLTHOFF, of the University of Utrecht (*Zeit. Unters. Nahrungs- und Genussm.*, 1921, xli, 112–122), prefers the indicator method to the hydrogen electrode. Neutral red is used as the indicator. The hydrogen ion concentration is a minor factor in judging a drinking water. However, if it and the bicarbonate content be known, the total carbonate content may readily be calculated.

J. S. H.

Talc and Soapstone. (*U. S. Geological Survey Press Bulletin No. 476*, August, 1921.)—Although talc is a mineral that is most widely known in the form of talcum powder, it is extensively used in the industries. The pure mineral is known as talc and the massive rock that contains it is known as soapstone. Nine-tenths of the talc and soapstone mined is ground and used as a filler in paper and in rubber, as foundry facing, and in many other ways.

The United States is by far the greatest producer of talc and soapstone, and it consumes even more than it produces. In 1919 it produced 68 per cent. of the world's supply and consumed 79 per cent.

The production of talc and soapstone in 1920 exceeded that in any previous year both in quantity and in value, according to Edward Sampson, of the United States Geological Survey, Department of the Interior. The sales in 1920 amounted to 224,290 short tons, valued at $3,090,265, an increase in 1920 over 1919 of 21 per cent. in quantity and 31 per cent. in value. The quantity exceeded by 2 per cent. that of 1917, the previous record-quantity year, and the value exceeded by 15 per cent. that of 1918, the previous record-value year.

The quantity of talc reported to the Geological Survey as ground was 178,505 tons, valued at $2,142,894, or 18 per cent. more than in 1919. The value of the ground talc was the highest on record, exceeding that for 1919 by 34 per cent. and that for 1918, the previous record-value year, by 15 per cent. The average price of ground talc in 1920 was the highest on record, namely, $12 per short ton, which may be compared with $10.55 in 1918 and 1919 and $8.42 in the prewar year 1913.

The manufactured soapstone sold amounted to 19,707 tons, valued at $709,400, not the highest annual output recorded, but the highest annual value.

Silica Brick Industry. (*U. S. Geological Survey Press Bulletin No. 476*, August, 1921.)—The refractory silica brick industry in the United States continued to make progress in 1920. These brick are used principally in by-product coke ovens, in open-hearth steel furnaces, in copper reverberatory furnaces, and in the glass industry, in which they must withstand high temperatures, such as would fuse ordinary clay fire brick. They also withstand abrasion well. The output in 1920, as estimated by Jefferson Middleton, of the United States Geological Survey, was 255,000,000 brick, valued at $15,540,000, or $60.94 a thousand, an increase of 18 per cent. in quantity and 32 per cent. in value as compared with 1919. The quantity marketed in 1920 was exceeded by that in 1917 and in 1918, when the stress of war caused an increase in the production of all refractories. The value in 1920 was exceeded only by that in 1918. The price per thousand in 1920 was the highest recorded. The output in 1920 was 46 per cent. greater, the value 307 per cent. greater, and the average price per thousand 178 per cent. greater than in 1913.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE INTENSITY OF SCATTERED X-RAYS IN RADIOGRAPHY.[1]

By R. B. Wilsey.

[ABSTRACT.]

In radiographing through the thicker portions of the human body, scattered X-rays have a considerable effect in fogging the image and thereby reducing the contrast and definition. In this investigation, a volume of water was used as the scattering material, inasmuch as its absorption and scattering characteristics are similar to those of human flesh. The relative photographic intensities of the scattered and primary radiation reaching the film were measured under a variety of conditions, showing the effects of thickness of scattering materials, sizes of cones or diaphragms between the tube and the scattering material, tube voltage, and filters placed between the scattering material and the film.

Under conditions similar to those in the radiography of thick parts, the scattered radiation reaching the film is roughly from four to ten times the intensity of the primary radiation. The intensity of the scattered radiation is small when the thickness of the scattering material is small, or when the X-ray image is diaphragmed to a very small size.

The removal of any scattered radiation necessitates an increase in exposure to compensate for the loss in total X-ray intensity. The exposure factors corresponding to various thicknesses of water and image sizes were computed from the experimental data.

The ratio of diffuse to primary focal radiation reaching the film was found to increase slightly as the tube voltage was increased.

Filters placed between the scattering material and the film diminish slightly the proportion of diffuse radiation. The filters are of no practical value, however, inasmuch as they do not improve radiographic contrast.

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* Communicated by the Director.

[1] *Am. Jour. of Röntgen.*, **8**, June, 1921, p. 328, Communication No. 102 from the Research Laboratory of the Eastman Kodak Company.

THE MUTUAL ACTION OF ADJACENT PHOTOGRAPHIC IMAGES.[2]

By Frank E. Ross.

[ABSTRACT.]

A REVIEW of the work of Kostinsky, Lau, Turner, Bellamy and others on the attraction and repulsion of neighboring star images was given. The factors which control the action were shown to be (1) *turbidity*, causing an attraction through optical reinforcement of the images on their adjacent sides. A formula was derived giving the amount of this attraction. (2) *Gelatine* disturbance, causing an attraction also. (3) *Developer* action, in which development of the images on their adjacent sides is retarded, owing to the products of reaction, as in the Eberhart effect. This leads to a repulsion. In the case of neighboring absorption spectral lines there is an additional effect due to a difference in sharpness of the edges which is caused by turbidity and halation.

Experimental data on the behavior of artificial double stars, close bright lines, and close absorption lines were described. It was shown that in experiments of this nature important differences develop depending on whether the exposures are normal or over-exposed. The contradictory results obtained by various investigators are thus explained. If the behavior is investigated by means of over-exposure, strong repulsions of neighboring images are found except in the case of absorption lines in which a strong attraction is found. In the case of normal exposure, which is of most interest in general, an attraction is usually obtained amounting to two or three microns. In order to reduce the affect, which enters as an error of importance in measurements of this kind, *the exposure must be reduced to a minimum.* In the case of over-exposures, considerable variation of the repulsive action was obtained by varying the developer. Curves for a number of developers were given in which it is shown that an attraction sets in, followed by a repulsion as the distance becomes less. It is important to make a further study of developers.

[2] *Astro. Jour.*, vol. liii, no. 5, June, 1921, p. 349. Communication No. 119, from the Research Laboratory of the Eastman Kodak Company.

ELECTROLYTIC MANUFACTURE OF p-AMINOPHENOL.[3]

By A. S. McDaniel, L. Schneider, and A. Ballard.

[ABSTRACT.]

NITROBENZENE was reduced electrolytically at 30° C. in strong sulphuric acid (90-91 per cent.), free from iron and heavy metals, using platinum electrodes, with a cathode current density of 6–8 amperes per 100 square centimetres, and anode density double. Glazed earthenware cells with porus diaphragms of thin, dense porcelain were used. Under these conditions minimum sulphonation was obtained. By washing the cell sludge with commercial hydrochloric acid, centrifuging, and treating with pure hydrochloric acid p–aminophenol hydrochloride was obtained, the yield being 40–50 per cent. on the nitrobenzene (exclusive of mother liquors which yield a further 10 per cent.). Apart from the cost of platinum, the most important economic factor is the necessity of providing for the cheap concentration of the spent acid. Cost of upkeep, owing to the excessive corrosive action of the matrials on the apparatus, is also considerable.

Atomic Weight of Germanium.—(Correction.) John H. Müller of the University of Pennsylvania has determined the atomic weight of germanium by heating a known mass of potassium fluogermanate in a current of hydrogen chloride, and weighing the residual potassium chloride (*Jour. Am. Chem. Soc.*, 1921, xliii, 1085–1095). Seven determinations gave, as an average, an atomic weight of 72.418 for germanium. J. S. H.

Prof. C. Runge, of Goettingen, has sent to *Nature* a list of men of science in Germany who have died since the beginning of the war. Among them are: Physicists—Hittorf, Riecke, E. Mach, Helmert, W. Voigt and Elster; chemists—E. Fischer and A. von Baeyer; mathematicians—Lexis, R. Dedekind, Frobenius, Cantor, Staeckel, Thomae and T. Reye; astrononers—von Auwers, Schwarzschild, Bruns, and W. Foerster; botanists—Voechting, Solms-Laubach, W. Pfeffer, whose investigations led to the conception of osmotic pressure, and Schwendener. G. F. S.

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[3] *Trans. Amer. Electrochem. Soc.*, 1921, p. 319–327, Communication No. 69, from the Research Laboratory of the Eastman Kodak Company

The Time Interval between Absorption and Emission of Light in Fluorescence. R. W. WOOD. (*Proc. Royal Society*, A 700.)—When ultra-violet light of short wave-length is absorbed by freshly formed mercury vapor the latter fluoresces with a bluish green light. That an interval elapses between the absorption of light and the appearance of the fluorescence is shown by the following experiment. A bent tube of fused quartz containing a little liquid mercury is exhausted and sealed. That leg of the tube in the lower end of which is the mercury is supported so as to be vertical. A flame placed beneath causes the mercury to distil into the distant end of the tube. Light from an aluminium spark passed through a hole in a metal screen and traversed the vapor in the tube. Except at the walls where the speed of the rising vapor was small, there was no trace of fluorescent light in the part of the tube where the light passed through the vapor, but two or three millimetres above the green light appeared. The time required for the vapor to rise through this short distance is the interval between excitation and appearance. To measure the time more accurately a phosphoroscope was specially designed. By its use the interval in the case of mercury vapor was found to be about one fifteen-thousandth sec.; for uranium glass, less than one four-hundred-thousandth sec. The duration of the phosphorescence of barium platino-cyanide came out equal to only one four-hundred-thousandth sec., while for fluorescence the duration was less than .00000044 sec.

Fluorescene, eosine, rhodamine, etc., are transformed into non-fluorescing bodies with absorption bands different from those of the parent substance. All fluorescing solutions are made from organic compounds with the single exception of concentrated solutions of some uranyl salts. "The idea occurs to one as to whether the phenomenon may not perhaps be associated with the natural break-down of uranium." G. F. S.

Asphalt Production in 1920. (*U. S. Geological Survey Press Bulletin No. 476*, August, 1921.)—The quantity of native asphalt and native bitumens sold in the United States in 1920 was 198,497 short tons, valued at $1,213,908. This was an increase of 125 per cent. in quantity and of about 78 per cent. in value over 1919. Gilsonite was reported from Uinta County, Utah, wurtzilite (or elaterite) from Duchesne County, Utah, and grahamite from Pushmataha County, Oklahoma.

The sales of manufactured asphalt obtained from domestic petroleum amounted to 700,496 short tons, valued at $11,985,457, or $17.11 a ton. Compared with 1919 these figures indicate an increase of 14 per cent. in quantity and 37 per cent. in value.

The sales of asphalt manufactured in the United States from Mexican petroleum in 1920 amounted to 1,045, 779 short tons, valued at $14,272,862, or $13.65 a ton. This was an increase of 55 per cent. in quantity and of 85 per cent. in value over 1919.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION. VIII. THE NUTRITIVE VALUE OF THE PROTEINS OF TOMATO-SEED PRESS CAKE.[1]

By A. J. Finks and Carl O. Johns.

[ABSTRACT.]

A DIET in which tomato-seed press cake furnished the sole source of protein and water-soluble vitamine enabled albino rats to grow at the normal rate. Such a diet was made adequate by the addition of starch, a suitable inorganic salt mixture, butter-fat, and lard. Normal growth was also obtained when the butter-fat of the above diet was replaced by lard.

THE APPLICATION OF OPTICAL METHODS TO THE EXAMINATION OF INSECTICIDES AND FUNGICIDES.[2]

By George L. Keeman.

[ABSTRACT.]

ATTENTION has been called to the application of optical-crystallographic methods for the identification of crystallizable chemical salts in insecticides and fungicides. The Bureau has found the use of such methods of value in many instances. A single method of procedure, particularly suitable for microanalysts who have not had extensive training in crystallography and mineralogy, has been outlined.

* Communicated by the Acting Chief of the Bureau.

[1] Published in *Am. J. Physiol.*, 56 (1921), 404.

[2] Published in *J. Am. Pharm. Asso.*, 10 (1921), 336.

THE MINERAL CONSTITUENTS OF POTATOES AND POTATO FLOUR: EFFECT OF PROCESS OF MANUFACTURE ON COMPOSITION OF THE ASH OF POTATO FLOUR.[3]

By C. E. Mangels.

[ABSTRACT.]

SAMPLES of fresh potatoes from different sources show differences in the amounts of mineral constituents present. Potato flour contains a smaller relative amount of total ash, and a very slightly smaller percentage of potash than the corresponding fresh potato. The relative distribution of different mineral constituents in the ash is not appreciably changed during the process of manufacture of the flour. Insofar as mineral constituents are concerned, the nutritive value of potato flour is practically the same as that of the fresh potato.

Annual Meeting of the French Society of Industrial Chemistry.—The newly formed Society of Industrial Chemistry in France will hold a meeting from October 9th to 12th, both dates inclusive, at the Conservatory of Arts and Trades in Paris. The opening session will be held under the chairmanship of Mr. Dior, Minister of Commerce. Thirty-four sections, covering all departments of applied chemistry will be provided, and many of the contributions will be by eminent specialists. The sessions for scientific business will close on October 11th at 5 o'clock, on which occasion the chair will be occupied by Mr. Louch Eur, minister of the recently evacuated regions. In the evening a banquet will be given at the Palais d'Orsay, under the presidency of Mr. Lefebvre du Prey, Minister of Agriculture. The last day will be occupied by excursions to manufacturing establishments. From October 7th to 16th an exposition will be held in the Conservatory of Arts and Trades, under the auspices of the society, which exposition, being merely initiative, will consist of but two sections: Apparatus for laboratory use and industrial control; dyestuffs. Many French establishments have already signified intentions to exhibit. H. L.

[3] Published in *J. Ind. Eng. Chem.*, 13 (1921), 418.

NOTES FROM THE U. S. BUREAU OF MINES.*

LABORATORY STUDIES OF THE TRENT PROCESS.

By O. P. Hood.

DURING the war certain suggestions concerning power production were made by Mr. Walter E. Trent to the War Inventions Board, and at the request of the War Department, facilities for experimental work were provided on the grounds of the Bureau of Standards. The experiments were along the line of controlling the conditions of combustion in a closed space. In order to reduce slag troubles, experiments were carried out for removing ash from powdered coal. After the war, work along this line was continued, resulting in the Trent Process, which agitates or beats together powdered coal, water and oil. A new technology had previously been given to ore preparation by the use of small quantities of oil in water with froth flotation, and although the methods, results, and mixtures of the Trent process were quite different, yet the same physical phenomena of differential wetting were used, and the possibility of there being interesting results in full technology was evident. A coöperative agreement was entered into, whereby the Bureau of Mines was to investigate the underlying physical and chemical facts and make them public, and the Trent Corporation was to pay the cost of the investigation.

The several reports as made have been available to any one interested, and are now to be published. While the Bureau of Mines felt justified in investigating the physical phenomena so far as might be done in a laboratory, and so far as public interest might reach, no attempt was made to discover the commercial possibilities which development might bring. The question of commercial possibilities must be left for commercial enterprise to answer.

Briefly, the process consists in agitating together powdered coal, water and oil. This produces a partly de-ashed plastic fuel, called

* Communicated by the Director.

an amalgam, the oil selecting the coal particles and largely excluding the water and ash. The amalgam can be freed from water mechanically held by working much the same as butter is worked. The amalgam can be burned in several ways; it may be shoveled, or forced through pipes by pressure; it can also be stored, under water if desired.

The laboratory results immediately suggest many interesting possible applications: (1) For pulverizing fuel wet grinding presents many advantages over dry grinding, provided the water can be eliminated afterwards; (2) to be able to reduce the ash in coal may make available great quantities of low-grade coals and material now considered as waste at the mines; (3) if an oil is used which can be distilled at a temperature below the distilling temperature of the coal, powdered fuel is reclaimed from the amalgam and the oil may be reused. If a heavy oil be used and distilled to dryness, a coke product may be recovered, although the coal used may have had no coking quality. If the distillation proceed only to a heavy pitch, a mass suitable for briquetting may be made; (4) in distilling oil mixed with a finely powdered material, the distillates are similar to those obtained by distilling under pressure, so that the distillation of an amalgam of coal and oil gives quantities often more favorable than the sum of the separate distillations of the coal and the oil; (5) the amalgam can be used for a gas-making fuel, and gas-house tar emulsions can be dehydrated by mixing with powdered coal, the amalgam being retorted for further gas making; (6) graphite ore can be separated from its gangue, and coke can be separated from flue dust by using the Trent process. Clean coal in anthracite sludge will make an amalgam if oil is added.

The brief sketch of possibilities revealed by small-scale laboratory work shows that the field for investigation and development is large. The general results show that real benefits are physically possible by treating coal in this manner. The Bureau has interested itself more particularly in the ash separation phenomenon or the cleaning of coal, and in the distillation of the amalgam. Details of the experimental work on ash separation are presented in a recent report, "The Trent Process of Cleaning Coal," by G. St. J. Perrott and S. P. Kinney. Results of the distillation work will be discussed in a future article.

SEPARATION OF SPHALERITE, SILICA AND CALCITE FROM FLUORSPAR.

By John Gross.

Southern Illinois and Kentucky are credited with approximately 90 per cent. of the fluorspar production of the United States. A small amount of high-grade acid spar is obtained from the ore by hand sorting; the greater part, however, is recovered by jigs and tables as gravel spar containing approximately 85 per cent. calcium fluoride. In the jigging and tabling operations, galena is recovered, and enough silica and calcite are removed to raise the calcium fluoride content of the gravel spar to 85 per cent. However, the removal of silica and calcite results in a large loss of spar. With increasing depth in the mines, zinc sulphide, sphalerite, is encountered in increasing quantity and the removal of this has become a serious problem. While the sphalerite can be fairly well removed from the spar by present milling methods, a marketable zinc concentrate can not be made.

In experiments made on fluorspar ore from Southern Illinois, by the mining experiment station of the U. S. Bureau of Mines, at Rolla, Missouri, in coöperation with the Missouri School of Mines and Metallurgy, two methods of treatment were worked out. One involves electrostatic separation, and the other flotation. Details of the methods are given in a short report recently issued by the Bureau.

LEACHING IRON ORES FOR PHOSPHORUS NOT PRACTICABLE.

By R. M. Winslow.

The phosphorus content of an iron ore is a determining factor as regards the value of an ore and its metallurgical treatment. The obvious advantages that would pertain to a cheap method for removing phosphorus by leaching has led the Bureau to make some laboratory tests to determine whether it is economically possible to reduce the phosphorus content appreciably by leaching. Sulphuric acid proved the best solvent, but the highest extractions were negligible from a commercial standpoint. The conclusion is that the method is not commercially feasible. Further details will be found in a short paper recently published by the Bureau.

The Mass Spectra of the Chemical Elements. F. W. ASTON. (*Phil. Mag.*, July, 1921; *Nature*, June 23, 1921.)—By continuing his experiments with the mass spectrograph the Clerk Maxwell Student of the University of Cambridge causes the positive rays to reveal that the element nickel is made up of two isotopes, the stronger line coming from a constituent of atomic weight 58, and the weaker from one of atomic weight 60. "The intensities of the lines are about in the ratio 2:1, and this agrees with the accepted atomic weight 58.68." In the discharge tube vapor of nickel carbonyl mixed with carbon dioxide was used.

When selenium in the compound selenium hydride and tellurium as tellurium methyl were investigated complete failures resulted. "The failure is unfortunate in the case of Te on account of its well-known anomalous position with respect to I in the periodic table; in the case of Se particularly so for the following reasons: If the accepted atomic weight is even approximately correct this element must have one isotope at least of atomic weight greater than 78. But the numbers 79, 80, 81, 82, 83, 84 are already filled by isotopes of Br and Kr, so that it is extremely probable that one of the isotopes of Se has an atomic weight identical with one of an element having a different atomic number, *i.e.*, is an isobar. The latter are known to exist among radioactive elements, but none have so far been discovered during the work on mass spectra."

Iodine, investigated in the form methyl iodide, gave one line only and this a strong one, corresponding to atomic weight 127. "This proves iodine to be a simple element in an unequivocal manner, a rather unexpected result since all the speculative theories of element evolution, by Van den Broek and others, predict a complex iodine. Kohlweiler not only deduces from theory five isotopes of iodine, but also claims to have achieved a considerable separation of them by diffusion." Antimony and tin gave no definite results. Xenon was tried again under more favorable conditions. The results corroborate the existence of the five isotopes previously announced and suggest the possibility of two additional ones.

By experiments on negatively charged chlorine it is concluded that the isotopes of this element have the atomic weights 35 and 37, while there may be a further one, 39.

The following remark of the author throws light upon the difficulties he is encountering and overcoming. "The particular method of generating positive rays employed by means of a large discharge tube is only suitable for investigating elements which have themselves a reasonably high vapor pressure or are capable of forming compounds which possess that necessary property. To the first group belong the elementary gases, to the second such elements as carbon and boron. Unfortunately the majority of the elements, including all the metals except mercury, do not satisfy these conditions to any great extent. It is therefore natural that as elements less and less suitable were employed the work grew progressively more and more difficult and the results either inconclusive or entirely negative."

G. F. S.

THE FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

Dr. Carl L. Alsberg, Stanford University, California.
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Mr. Fred Denig, 211 Whedbee Street, Fort Collins, Colorado.
Mr. Harold Goodwin, Jr., 3927 Locust Street, Philadelphia, Pennsylvania.
Mr. J. H. Granbery, 77 Lenox Avenue, East Orange, New Jersey.
Mr. Bayard Guthrie, 4414 Fifth Avenue, Pittsburgh, Pennsylvania.
Mr. R. A. Marriott, 811 Higgins Building, Los Angeles, California.
Mr. Thomas S. Martin, 3rd, 7205 Cresheim Road, Germantown, Philadelphia, Pennsylvania.
Mr. Emile G. Perrot, The Boyertown Building, 1211 Arch Street, Philadelphia, Pennsylvania.
Mr. G. Berkeley Reed, 80 St. James Place, Brooklyn, New York.
Mr. Edward Rittenhouse, Aldan, Pennsylvania.
Mr. John B. Rumbough, P. O. Box 224, Reno, Nevada.
Mr. W. Hinckle Smith, Bryn Mawr, Pennsylvania.
Mr. Wilson E. Symons, 41 East 42nd Street, New York City, New York.
Mr. Earl H. Tschudy, 613 Canal Street, Lebanon, Pennsylvania.
Mr. J. M. Weiss, 40 Rector Street, New York City, New York.
Mr. Charles H. Whitney, Whitney-MacDonald Company, Tioga and Memphis Streets, Philadelphia, Pennsylvania.
Mr. Lucien I. Yeomans, 1327–53 W. Jackson Street, Chicago, Illinois.

NECROLOGY.

Mr. Charles O. Bond, Collegeville, Pennsylvania.
Mr. Henry F. Colvin, 3906 Fairmount Avenue, Philadelphia, Pennsylvania.
Mr. Edwin Walker Kelly, 312 Wisconsin Avenue, Oak Park, Illinois.

LIBRARY NOTES.

PURCHASES.

Barrowcliff, M., and F. H. Carr.—Organic Medical Chemicals. 1920.
Bowden-Smith, E. C.—Efficiency of Pumps and Ejectors. 1920.
Georgievics, G. Von.—Chemical Technology of Textile Fibres. 1920.
Griffin, R. C.—Technical Methods of Analysis. 1921.
Griffiths, E. A.—Engineering Instruments and Meters. 1921.
Edridge-Green, F. W.—The Physiology of Vision. 1920.
Van der Bijl, H. J.—The Thermionic Vacuum Tube. 1920.

GIFTS.

Experiments and Observations on Electricity made at Philadelphia in America, by Mr. Benjamin Franklin and communicated in several letters to Mr. P. Collinson, of London, F.R.S. 86 pages, folded plate, 8vo. London, 1751. (From Mr. Max Levy.)

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BOOK NOTICES.

Organic Compounds of Mercury. By Frank C. Whitmore, Ph.D., Northwestern University. 8vo., 380 pages and index. The Chemical Catalog Company, Inc., New York, 1921.

This is one of the series of monographs, issued under the editorship of the American Chemical Society, a series which will be of great value to American chemists. The organic compounds of mercury have been extensively studied from the point of view of pure science, but this study has acquired in recent years a practical phase in consequence of the desire for a mercurial compound which does not ionize under ordinary conditons and may, therefore, be usable in comparatively large doses in specific diseases, without involving the well-known poisonous actions of the common mercury salts.

The whole field of organo-metallic chemistry is interesting especially in its complexity. One of the earliest compounds of the class was the substance long known as "Cadet's fuming liquor," obtained empirically in 1760 by the Paris apothecary whose name it bears. Bunsen showed many years later that the principal ingredient is a compound of methyl, arsenic and oxygen, and he gave to the arsen-methyl group the name "kakodyl." His wonderful series of researches showed the wide range of combinations possible, and led, among other results, to the discovery of kakodylic acid, with its interesting property of much lower toxicity than the content of arsenic would indicate. At that time the relation of ionization to chemical activity was not known.

Doctor Whitmore points out that the arsenical compounds have received much more publicity than the mercurials, due probably to the prominence which the former have both in therapeutics and toxicology. The preparation of the arsenical compound dates from the eighteenth century, but the first production of a recognized organo-mercury compound appears to have been in 1843, when A. W. Hofman obtained one from the reaction of aniline and mercuric chloride. The exact structural formula of this is not known. Definite production of the mercury compounds dates from 1850, when Frankland noted the reaction of mercury on ethyl iodide and two years later ascertained that methyl iodide gives with mercury under the influence of sunlight, a methyl mercury iodide, CH_3HgI. The earlier steps in the development of the chemistry of these compounds are indicated in the book, and one is impressed with the immense number of the known forms and their complexity. As might be expected, most of them are poisonous, some powerfully so. In fact the discovery of mercuric methyl and mercuric ethyl gave rise to some very acrimonious correspondence in the pages of the *Chemical News* (1865, xii; 1866, xiii) owing to the fatal poisoning of two assistants in the laboratory of St. Bartholomew's Hospital in London, in which the original investigations by Frankland and afterwards Odling were carried out. Doctor Ulrich, a German chemist, and Doctor Sloper, an Englishman, suffered from chronic poisoning as a result of considerable work in connection with the preparation of the substances, and Doctor Phipson accused Doctor Frankland of having sacrificed his assistants. The charges and the

counter-charges were continued for some months, but it does not appear that the principals, Frankland and Odling, were in the least culpable. At the time these two compounds were first prepared, they were among other properties distinguished by their high refractive and dispersive powers, and it was suggested that they might be available for filling hollow prisms. Their extreme poisonous qualities would surely render them unavailabe for such use.

Doctor Whitmore's book is a most valuable addition to the literature of a special class of compounds, and exhibits on every page the painstaking, laborious search of an extensive literature and the arrangement of a great mass of facts in a convenient and vivid form.

HENRY LEFFMANN.

A COURSE IN QUALITATIVE CHEMICAL ANALYSIS OF INORGANIC SUBSTANCES. By Olin Freeman Tower, Ph.D., Adelbert College. Fourth edition, revised, 8vo., xv-90 pages. Philadelphia, P. Blakiston's Son & Co. $1.50 net.

This being the fourth issue of the work it is evident that it has had success. It contains in the main the usual procedures for the separation of the metals into groups by the familiar group-reagents, and the subsequent identification of individuals by special tests. The introduction of the ionic theory has involved considerable explanation of the principles of many of the reactions, so that the modern manuals are less empiric than those of fifty years ago. The preliminary qualitative analysis scheme has long been in favor with teachers, but it is a question whether it might not be substituted by something having a more distinctly quantitative character. The book presents the subject in pretty full detail and gives numerous explanations.

HENRY LEFFMANN.

DAIRY BACTERIOLOGY. By Orla Jensen, Ph.D., Polytechnic College, Copenhagen. Translated by P. S. Arup, B.Sc., F.I.C. 8vo., xii-174 pages, index and 70 illustrations. Philadelphia, P. Blakiston's Son & Co. $3.00 net.

Denmark is one of the great dairy countries of the world, and Danish chemists have contributed very largely to the progress of the science. We may be sure, therefore, that this book will contain a large amount of information on the field to which it is devoted. There is no problem in general hygiene more important and more difficult to handle than the milk supply for cities. The ease with which moderate adulteration may be practised, and the temptation thereto, coupled with the liability of the material to acquire injurious conditions without specific indication thereof, has made the regulation of the milk supply one of the most formidable questions in municipal management. A large part of this management is in the control of the cleanliness of the milk, using the word in its widest sense. The bacteriology of market milk has been extensively studied, and has been found very complex. The work in hand begins with an account of the general morphology of minute organisms, classifying

"micro-organisms" as living forms that cannot be seen by the unaided eye. Leeuwenhoek is, as is customary, credited with the discovery or, at least, the first recorded observation of bacteria, but it is somewhat doubtful whether he saw any of the organisms that are now included under that title.

The work is commendable. It cannot be said that it is superior to American works already available, but it is fully up to the required standard. Originating in Denmark and translated in England, there is a liability to an insufficient presentation of American standards and practises. An instance of this is found on page 88, where it is stated that in order to avoid marketing defective tins of condensed milk, the manufacturer should retain the product for a short time. American manufacturers of canned goods have automatic apparatus for detecting leaky cans, and have no trouble from that source.

All those interested in dairy bacteriology will find a large amount of useful information, well expressed, in this book. It is well printed and quite liberally illustrated.

HENRY LEFFMANN.

A TEXT-BOOK OF ORGANIC CHEMISTRY. By Joseph Scudder Chamberlain, Ph.D., Massachusetts Agricultural College. Small 8vo., xliii–927 pages and index. Philadelphia, P. Blakiston's Son & Co. $4.00 net.

This work is in the form of the ordinary text-books of organic chemistry, and treats the subject in about the usual manner. Perhaps the character of it can be best expressed by a quotation from the preface. After advising the student to "go through the difficulties and not over or around them"—advice which some students will take and some will not—the author says that he has "endeavored to present the subject in a sufficiently elementary manner so as not to be beyond the grasp of the student in his first course in organic chemistry, yet to make the book comprehesive in that it covers the entire field by taking up practically all the important groups of compounds." An examination of the work indicates that this intention has in the main been reached. The book contains a very large amount of information well expressed and well arranged. It may be a question whether the structural formulas, which are very numerous, are not printed with type unnecessarily large. This takes up space and makes the book much larger for the proportion of the matter in it. One criticism must be expressed. The benzene ring-symbol is almost always wrongly written. Kekulé, in his original paper (*Ann. d. Chem. u. Pharm.*, 1865, v. 137, 129) suggested that the plain hexagon should be taken to indicate the unmodified benzene, and gives a drawing consisting of such a figure with a suggested orientation by letters. To attach CH groups to the angles of such a figure, as is done frequently in this work, is to indicate compounds much more complicated than really intended, and to burden the student with unnecessary symbols. The hexagons used have the same defect as noted above in the other formulas, for they are much too large.

Only a brief notice is given to enzymic action, and the term "catalysis," though noted in the book, is not in the index. Methyl alcohol is stated to have a disagreeable odor and to be used in denaturing common alcohol, but these statements concern the crude product, although given in connection with the description of the pure substance.

HENRY LEFFMANN.

ESSENTIALS OF PHYSICS. By George A. Hoadley, C.E., Sc.D., Swarthmore College. Revised editon, 534 pages, index and 556 illustrations, including several full page plates, 12mo. New York City, N. Y., American Book Company, 1921.

PHILOSOPHY AND THE NEW PHYSICS. An Essay on the Relativity Theory and the Theory of Quanta. By Louis Rougier, Docteur ès Lettres. Authorized translation from the author's corrected text by Morton Masius, M.A., Ph.D., Worcester Polytechnic Institute. xv–155 pages and index, 12mo. Philadelphia, P. Blakiston's Son & Co. $1.75 net.

Placed thus, these two books may be said to represent the alpha and omega of modern physics. Dr. Hoadley's book deals in a simple and straightforward manner with the whole field of physics as proper to be presented to the beginner; Rougier deals with abtruse phases of it, one portion of which—relativity—has obtained a fame that has made the term almost a household word.

Taking the "Essentials" first—as is, of course, the natural method—we find that in small and convenient compass, the author has embodied the general principles of physical science as known to-day, and the many applications of them to affairs of practical life and to further research. One of the interesting additions is the notice of camouflage. The allusion to the value of protective resemblance in animals, shows how the science of inanimate things spreads into biology, while the vivid pictures of the camouflaged liner given as a frontispiece, renews our thoughts of the expedients of the late war. The extensive use of illustrations serves greatly to aid the student and to awaken his or her interest. The convenient size and clear type will be of no little service in its use as a text-book.

Turning to the other work, we find first, a brief preface in which the translator suggests that the book seems to mark a measurable advance towards a junction of the broad streams of philosophy and scientific inquiry. It is within the memory of many teachers, now living, that physics was generally called natural philosophy, a phrase which apparently lingered longer among English-speaking scientists than with those of other nations, for Taine says in one of his essays, somewhat deprecatingly, "In England, a barometer is still called a philosophic instrument." Physicists, Dr. Masius tells us, are usually too much occupied with their special fields to give attention to philosophic inquiry; it is probably true of most of them that the mental make-up leads them to be impatient of the methods of philosophers. Yet the whole voice of science is suggestive of monism, that is, a unity of origin and an identity of type, and it is opportune, therefore, in this very decidedly materialistic age that those who can deal with the fields of physics and metaphysics, as they may be conveniently grouped should take up the burden of joining them. The present work is an

effort in this direction by a competent writer, and his French text has been admirably converted into English, so that a wider field of usefulness for the work will be secured.

HENRY LEFFMANN.

ECONOMIC PAPERS ON KENTUCKY GEOLOGY. By Willard Rouse Jillson, Director and State Geologist. x–295 pages, index and 115 illustrations (maps, diagrams and photographs), 8vo. Frankfort, Ky., The Kentucky Geological Survey, 1921.

This is a collection of papers and reports on the geology of some of the important deposits in the State of Kentucky, oil and gas, shale, asphalt rock and fluor-spar being especially noted. The Kentucky-West Virginia region is evidently of great potential importance in view of the trend of industrial life, and the study of any portion of it by a competent authority is welcome. Mr. Jillson has given us a very interesting and valuable book. One of the most important of the papers is that on rock asphalt. The earnest movement towards better roads will find no more appropriate direction than in the southern States, and we learn from the book that the discovery of a deposit of rock asphalt in Kentucky means a material improvement in the roads of the State. Unlike the asphalts so much used in our eastern cities, which are artificial mixtures of soft material with various minerals, the Kentucky product, like that of France, is ready for use when mined, and is laid without heating. Analysis shows that the mineral base of the rock is a true siliceous sand, each grain being coated with the bituminous material. Analyses are given showing nearly 7 per cent. of asphalt in the rock as mined. In addition to the information about asphalt, interesting articles are given on oil shales, oil and gas, and notes on general surface geology. The book is a most timely contribution to economic geology, and the numerous photographs make it interesting even to the general reader.

HENRY LEFFMANN.

VOLUMETRIC ANALYSIS FOR STUDENTS OF PHARMACEUTICAL AND GENERAL CHEMISTRY. By Charles H. Hampshire, B.Sc., F.I.C. Third edition, 120 pages and index, 12mo. Philadelphia, P. Blakiston's Son and Company, 1921. $1.75 net.

Though a small book, this contains a large amount of information, as the type used is proportionate in size. It is, however, quite clear and easily read. The text is arranged for special lines of work, and is divided into two styles, the paragraphs in larger type being descriptions of standard methods generally applicable, while those in smaller type are especially intended to exercise the student in the procedures of the British Pharmacopeia. Metric weights and measures are used throughout, which is gratifying, but it is to be regretted that the spelling "gramme" is retained. The reactions involved in the processes are mostly explained by equations. The typography, paper and printing are exceptionally good, and the size of the book makes it very convenient for the student. It is probable that in many of the procedures the book will be adapted to American methods, but American teachers will have to keep always in mind the liability of British methods to depart from our practise.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Volumetric Analysis for Students of Pharmaceutical and General Chemistry, by Charles H. Hampshire, B.Sc. (London), F.I.C. Third edition, 124 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1921. Price $1.75 net.

Statique Dynamique, par M. Steyvaert, Correspondant de l'Académie Royale de Belgique, Professeur à l'Université de Gand. 205 pages, illustrations, 8vo. Gand, Van Rysselberghe & Rombaut, 1920. Price, in paper, 20 francs.

National Advisory Committee for Aeronautics: Technical Notes No. 52, A New Method of Testing Models in Wind Tunnels, by W. Margoulis. 19 pages, plate, quarto. No. 57, The Caproni Seaplane, by Max Munk. 14 pages, photograph, quarto. No. 59, The Dynamometer Hub for Testing Propellers and Engines During Flight, by O. Enoch. 18 pages, plates, quarto. Washington, Committee 1921. Report No. 111, The Variation of Aerofoil Lift and Drag Coefficients with Changes in Size and Speed, by Walter S. Diehl. 10 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

Some Experiments on Thermal Diffusion. T. L. IBBS. (*Proc. Royal Society,* A 700.)—From theoretical considerations Dr. S. Chapman deduced that "a temperature gradient applied to a uniform mixture of two gases will tend to produce non-uniformity of composition, the heavier and larger molecules diffusing toward the cooler side, and the smaller and lighter molecules diffusing toward the hotter side. This phenomenon was termed 'thermal diffusion.' The difference in composition due to thermal diffusion increases until it is balanced by the opposite effects of ordinary diffusion, when a steady state will be reached. The effect is greatest when the gases are mixed in nearly equal proportions by volume, and will be greater the more unequal are the masses and diameters of the gas molecules."

A mixture of hydrogen and carbon dioxide was used. This flowed through a cylinder in the axis of which was a spiral of platinum wire heated by an electrical current. The gas from the peripheral part of the cylinder and that from the axial part escaped by different outlets. The two streams of gas were led into a differential katharometer calibrated so that the deflections of its galvanometer could be translated into composition differences. The excess of hydrogen was always found on the side of the hotter gas. Raising the temperature of the spiral increased the degree of separation. For instance, in the case of one mixture raising its temperature from 25 to 570° C. caused the percentage separation to increase from .045 to 3.52. In all cases maximum separation was got for mixtures containing from 50 to 60 per cent. of hydrogen. Only about three minutes was needed for this thermal diffusion to take place.

G. F. S.

Preparation of Plates for Ultra-violet Light.—Photography offers the only satisfactory method for recording the phenomena of ultra-violet and infra-red light, inasmuch as these rays are invisible to the unaided eye. It is fortunate, indeed, that the ordinary silver salts are sensitive over so wide a range. It is true that many of the invisible rays can be observed by means of a fluorescent screen, but this does not furnish a permanent record. Research has shown a wide range of both forms of rays, and one serious interference with investigations is that ordinary glass is practically opaque to all vibrations above the violet, so that resort must be made to quartz, fluospar and other substances, either rare or difficult to obtain in clear condition. The recent inventions, however, by which quartz can be cast in the form of clear plates and tubes will be of advantage in these researches. In a recent issue of the *Journal de Physique* (1921, ii, 156) Duclaux and Jeantet describe a method of treating ordinary plates so as to increase greatly the sensitiveness to the higher vibrations. They had need of plates sensitive beyond 1900 angström, and tried the procedure advocated by Schumann, but found it tedious and uncertain. Schumann plates are distinguished by the small proportion of gelatin, and it was thought that this condition could be secured by degelatinizing to a great extent ordinary plates. Trials of various methods, such as immersion in warm water, acid solutions, digestive enzyms, were without success, but a simple and satisfactory procedure was devised.

The plate is placed horizontally in a dish with dilute sulphuric acid (one volume of the strong acid to ten volumes of water), and kept for four hours at room temperature (about 77° F.), the temperature being a little higher than this at the beginning and a little lower at the end. They are then removed to a dish in which they are washed by a very slow current of water, as the remaining gelatin is tender. Thirty minutes will be a sufficient washing. They are then dried, which requires but little time on account of the small amount of gelatin present. Plates thus treated retain a thin layer of emulsion poor in gelatin and uniformly spread on the glass. This deposit is extremely sensitive to ultra-violet rays, but is also very fragile, and the authors recommend that before developing the surface should be coated with a thin film of collodion, the plate being immersed in the developing bath before collodion is quite dry. Although most commercial plates are adapted fairly well for this procedure, it is likely that trial with many forms will show some more suitable than others. For rays of much greater wave-length than above noted, these plates are ten times more sensitive than the best plates prepared according to Schumann's method, and at least 200 times as sensitive as the plate in its commercial form.

Another method for obtaining plates of high sensitiveness to short wave-lengths is by covering the emulsion with a layer of fluorescent substance. Such a substance absorbs, so to speak, the short waves and emits in turn waves of greater length, to which the gelatin is

transparent, and thus permits an action on the silver compound, hence the impression is made as if the gelatin was not present. For this method, substances giving blue or violet fluorescence should be chosen, and they should be dissolved in a liquid that will not swell the gelatin, and is not absorbed by it, since the efficiency of the process depends on the fact that the fluorescent rays act before the light enters the gelatin film. Water is, therefore, not applicable. The authors obtained good results with a solution of esculin in glycerol, but found most satisfactory results with lubricating oil. Many of the commercial forms of these have a distinct fluorescence due to hydrocarbons. It is sufficient to smear a few drops of such an oil over the emulsion by means of a wad of cotton. After exposure this film should be removed by means of ether or alcohol. A very thin fluorescent layer may be obtained by immersing the plate for a few minutes in a solution of the fluorescent oil in light petroleum or alcohol and allowing the solvent to evaporate. These procedures are simple and effective. They enable the operator to secure photographs of rays ranging from the extreme red to the limit of the ultra-violet. One slight defect is noted, a very small enlargement of the rays by irradiation, but this does not go beyond the twentieth of a millimetre.

The processes have been tried with many commercial plates, and the sensibility is found to be greater than with the sulphuric acid method. It is possible, indeed, to carry out an instantaneous spectrography. Detailed results with certain metallic spectra are given in the paper. H. L.

CURRENT TOPICS.

Studies of Desensitizers.—The interest in the application of phenosafranin in desensitizing photographic emulsions has led to many investigations, among which the most extensive so far reported are those communicated by A. and L. Lumière and Seyewetz to a recent meeting of the French Society of Photography and published in full in the current number of the society's journal (*Bull. Soc. Franç. d. Photog.*, 3, 1921, viii, 144). An abstract giving the principal data of the paper is herewith presented, taken from the *Photographic Journal of America.*

The inventor of the process, Lüppo-Cramer, has presented a large amount of information concerning it in special work. One property of phenosafranin is some objection to its use, namely, its high staining power on gelatin, and if a substance of equal power to desensitize but which has no staining power could be secured, a notable gain would be made.

Phenosafranin belongs to a type of colors containing what is termed a phenazin nucleus, and Lumière and Seyewetz directed the investigation first to ascertain if this particular molecular structure is the only one that determines the peculiar property or if other classes of bodies possess it. Further, it was advisable to ascertain if the desensitizing action is extended to panchromatic plates. The interesting question arises whether, if several desensitizers of apparently equal power are available, each has a specific adaptability to a given case. Lumière and Seyewetz also raise the question as to whether the action is chemical, physical or chemico-physical. It seems hardly worth while to discuss such a question until we have clearly determined what is meant by the several terms.

Fourteen colors, all forms of the safranin type, were tried in comparison with safranin. Of these, toluosafranin is doubtless nearest in composition to the standard. None of these substances was found to be fully equal to phenosafranin, and many were decidedly inferior. One of them, a very complicated derivative, was found to destroy to a certain extent the latent image, another was but slightly soluble, and one that approached closely the power of the standard, colors the gelatin quite obstinately. Several of them are not commercial articles, but were specially prepared by the investigators.

In the experiments, plates of the highest sensitiveness (not panchromatic) were used, all receiving the same exposure, and afterward immersed for two minutes in solutions of the colors ranging from 1 to 100 to 1 to 2000 in strength. The stronger solutions were first used, and then the tests made in solutions of gradually decreas-

ing strength. Development was carried out by the light of a candle 1.5 metres distant (about 5 feet), the light being reflected directly upon the developing dish, so as to have the plate exposed from above. The developer was paraminophenol, allowed to act for four minutes at about 17° C. (63° F.), the image being examined by transmitted light twice during the procedure, first after two minutes and then after three and a half minutes. If the picture thus obtained showed only a slight veiling, the procedure was repeated with panchromatic plates. The experiments seemed to indicate that certain molecular conditions are necessary to the desensitizing action—the presence of a phenazin nucleus and the substitution of amidogen groups in the benzene ring—but, notwithstanding that these conditions are fulfilled in the color known as neutral violet it has no marked desensitizing powers, and is inferior to neutral red, which approximates to phenosafranin in its action. Neutral red is a brownish-red dye, having little brilliancy, coloring gelatin only faintly, and much more easily removed than the safranins, but the proper impregnation of the plate to secure full measure of desensitization requires double the time that is required by the standard, that is, four minutes instead of two minutes. As noted above, the colors tried were not found to possess quite the power of phenosafranin, but one of them, chresosafranin, can be removed very quickly from the film.

The tests were then extended to panchromatic plates of wide range of color sensitiveness. The procedure was to photograph spectra on each plate, immerse, in darkness, for one minute, develop for one and a half minutes, also in darkness with diaminophenol, then continue development for two and a half minutes at 20 inches from a 16 c.p. electric bulb, covered by yellow papers, stained with tartrazin, giving a very good illumination. During this latter period the plates were examined by transmitted light four times for a period of three seconds each. Most of the substances tried were unsatisfactory, but tolyluene red and aurantia (a yellow dye) gave distinct desensitizing action.

The paper contains also the results of trials of substances not related to the safranins. Among these a drug, apomorphin hydrochlorid, was found to have a distinct effect, a somewhat remarkable fact. Picric acid is also not without effect, but acts more like a screen and the action differs with the strength of the solution.

They conclude that the action of the safranins is a specific desensitization and not a mere screening, inasmuch as the violet dyes of the type act as well as the red; moreover, if, before development, the color is washed out, the sensitiveness slowly returns and when all color is gone, the plate has resumed its susceptibility to light. Phenosafranin is so far the only material eminently adapted to desensitization in general, but where complete immunity from red light is not indispensable, aurantia will be found applicable, as it does not stain the fingers, is more easily removed by washing, and does not

involve, as phenosafranin does, the occasional employment of a decolorizing solution.

The Fuel Problem.—No greater problem is before the industrial world to-day than the economical use of fuel. Among the most recent contributions to the subject is an address by Sir George T. Beilby, delivered in the theatre of the (British) Institution of Civil Engineers, and published in *Chemical News* (1921, v. 123, 86). The following figures taken from the report of the U. S. Geological Survey give the coal production, including lignite and brown coal, for 1920. The total output was 1300 million metric tons, of which

	Per cent.
The United States of America produced	45
Great Britain and the British Empire	22
Germany	19
Other countries, ranging from 2½ per cent. downward	14
	100

One of the most significant features revealed by this survey is the remarkably rapid development in the winning and use of brown coal and lignite in Europe and particularly Germany. The output in Germany in 1919 had reached the huge figure of 93.8 million tons; but this was overtopped in 1920 by an output of 111.6 million tons—an increase in one year of nearly 18 million tons. The total European output in 1920 amounted to 140.7 million tons, made up as follows:

	Million Tons.
Germany	111.6
Czecho-Slovakia	19.7
Jugo-Slovakia	2.5
Austria	2.5
Italy	1.6
Netherlands	1.4
France	1.0
Spain	0.5

The output of ordinary coal in Germany for 1920 was 140.8 million tons. The brown coal industry in that country is of old standing; and its rapid development in recent years is based on sound knowledge and experience. Though in its natural state a less concentrated fuel than bituminous or anthracite coal, brown coal has many points in its favor. The chief of these is the low cost at which it can be won as compared with ordinary coal. Where extensive deposits of great thickness occur, these can be worked opencast and excavated by machinery. The winning of brown coal is thus on

an altogether different basis from coal mining, with its deep and costly underground roads and workings, which involve heavy costs for timbering, pumping, and ventilation. The manual labor required is much smaller in amount for a given output, and is of less highly specialized type; while the special dangers and uncertainties of coal mining are practically absent. The capital charges, being mainly on surface roads and on excavating machinery, are relatively light, as compared with the heavy initial and permanent charges involved in the sinking and equipment of shafts or mines. Brown coal, though it contains from 40 to 60 per cent. of water, is to-day by far the cheapest source of thermal units. Its further manufacture by drying, briquetting, and carbonization can be carried out close to the point of excavation, and under conditions favorable to production on a large scale, and, therefore, at a low cost.

The glowing accounts of this development which have appeared in the technical press during the past two years may have struck us as exaggerated; but the solid fact remains that the output of lignite in Germany last year was 111 million tons. Germany has already faced the fuel problem of the future so far as she herself is concerned

H. L.

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MODERN STEAM POWER STATION DESIGN.*

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INTRODUCTION.

THE reliable and economical production of power is one of the most vital subjects with which a public service company has to deal today. Always of importance, it has become doubly so now, with the high cost of labor and the growing scarcity and high price of fuel, and much careful study is being given the subject with a view to increasing economies of operation by improvements in design of plant and equipment and by bettering of load factor through centralization of power generation.

In like manner, but to a lesser degree, is this subject of importance to the large industrial companies. With them power is only one of the many items entering into the cost of a manufactured article and does not constitute their chief product, but increasing costs have had their effect on them too, and we find them more and more becoming either customers of the central station, or where they have need of much steam in their processes, paying particular attention to the design and operation of their generating equipment.

HISTORICAL.

At the time of the coming of the steam turbine, not much advance was being made in the art of power station design.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, February 10, 1921.

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Although several large and quite economical engine-driven stations had been built, they consisted principally in a repetition of practically standard equipment, and succeeding installations did not represent much advance over preceding ones. Electric drive of industrial equipment was not common and central stations supplied power principally for street railways, lighting and comparatively small motor installations.

The economical range of distribution was usually small, requiring a number of stations often unsuitably located for economical generation in an area that could be properly supplied from one or two turbine stations today. Most industrial plants had their own power stations, consisting generally of fire-tube boilers and noncondensing engines belt connected to long line shafts. Often the engines were located in parts of the factory remote from the boilers and connected with them through long steam lines.

The commercial adoption of the steam turbogenerator completely changed the existing order of things and so increased the importance of other power plant equipment as to make radical development necessary to adapt them to the new conditions. Essentially an alternating current piece of equipment on account of its high speed, the turbogenerator gave great impetus to the use of alternating current and in conjunction with the transformer increased the range of power distribution, permitting greater centralization in the generation of power with consequent greater latitude in the selection of a suitable site for the station.

The ability of the turbine to use superheated steam, higher steam pressures, and particularly high vacua with consequent great increase in economy, led to the adoption of the superheater, the almost universal use of the water-tube boiler and to great improvements in the design of condensing equipment. These things, together with the changes in type, size and speed of the prime mover, introduced new factors in power station design and made radical changes necessary.

The old idea, however, of uniform arrangement and repetition of equipment, common in engine stations, still prevailed and we find the early design of steam turbine stations based on the continued installation of the same type and size of equipment. Thus stations were laid out for vertical or for horizontal units, it being assumed that each succeeding unit would be similar in all respects to those previously installed.

IMPETUS DUE TO STEAM TURBINE.

The great increase in the use of central station power, and the greater economies in space and steam consumption lead to the design and installation of larger and still larger units, until today we have stations built and projected, with capacities of over 200,000 kw., and occupying space originally intended for half the capacity and with operating efficiencies considered impossible in the early days of the industry.

The Fisk Street Station in Chicago, the first of the large stations designed for steam turbines, was originally laid out for 5000 kw. units, considered in those days to be the largest size practical. Within six years, however, these were replaced by units of 12,000 kw. capacity and of sufficiently better steam consumption to make the substitution financially economical. After the installation of ten of these units, a 25,000 kw. unit was installed, followed by a 20,000 kw., a 30,000 kw., and a 35,000 kw. unit, making a total installation today of 230,000 kw. in a space originally intended for 70,000 kw. Other equipment in the station naturally had to keep pace with the increase in sizes of the main units. The boiler plant was started with 500 h.p. units, to be followed by 1200 h.p. and 1450 h.p. units.

PRESENT STATUS OF TURBINE DESIGN.

Experience with the operation of the larger size units within the past few years has brought out the fact that while they have justified themselves from the standpoint of economy of steam consumption and space occupied, they have not at the same time shown the reliability of the earlier and smaller units. The greater diameters and higher peripheral speeds of the larger units have magnified the importance of vibration, temperature changes, and other factors not so seriously affecting the smaller units. The fact that the rapid increase in size of units occurred during the war period when the quality of labor was poor and when quantity rather than excellence of production was the rule, has probably contributed to the difficulties experienced. There has, therefore, been a halt in the increase of size of individual units, and attention is being given to correcting difficulties and improving existing designs rather than planning for larger capacities. There is a feeling also that the economies of operation and space of still larger units are not commensurate with the investment tied up

in them and the large loss when they are not in service. We have reached a point where the economies to be gained from further increase in size of units seem not to be warranted. It may be that the working out of a super-power system, as is now proposed, will cause us to go to larger sizes, but for the present the economical limit appears to have been reached.

TWO SIDES TO STATION DESIGN.

There are two principal sides to the design of a steam power station, the economical and the mechanical. The first deals with the selection of the equipment and the working out of the station heat balance to give a kilowatt hour for the least cost; the other deals with the design of the structure and the arrangement of the equipment to give maximum ease of operation and maintenance. The first sets the station bogey, that is, it fixes the limits of economy possible with any given condition of operation. The second affects the cost of the station and therefore the fixed charges. There are more ways of solving the problem with consequently more chance for controversy as to the relative merits of various solutions. Different engineers treat the problem differently and local conditions often play such an important part that one cannot generalize and say that one type of arrangement is better than another. There are certain principles that apply to the general subject, however, that can be stated without risk of an argument.

I. ECONOMICAL FEATURES OF DESIGN.

Size and Characteristics of Load.

The first things to be determined in the design of a central station are the characteristics of the load, the load factor and the present and probable ultimate capacity to be provided. Each community, or industry, furnishes a typical load curve from which a start can be made. The load curve should cover as long a period as possible. From this the characteristics of the load, the load factor and the rate of growth can be approximately determined. With this as a basis, and modified by the possibilities of future increase of load, the size of the first installation and the probable ultimate capacity of the station can be decided.

Selection of Site.

The next important consideration is the selection of the site. Before any property is purchased for power station purposes, its

suitability from an engineering standpoint should be determined. Sometimes when he approaches the question of power station design, the engineer finds the site has been selected for him and is forced to make the best of what has been provided. This throws a handicap on the working out of a suitable design and may seriously affect the amount of the returns on the investment. Chief considerations in the selection of the site are the adequacy of water supply for condensing purposes, accessibility by rail or water, or both, for the delivery of fuel, and the location with reference to the delivery of the power generated. The site should be of ample area for the scope intended up to the ultimate capacity, including space for coal storage and outside electrical switching and transforming equipment. It is not always possible to procure a site, especially in the larger cities, that possesses all the requirements and is at the same time within economical transmission distance of the load. In this case it is necessary either to sacrifice some of the considerations or make provision for them elsewhere. In New York and Chicago, and in your own City of Philadelphia, sufficient areas are not available near some of the power station sites for the storage of emergency coal, and it has been necessary to provide for this on property remote from the stations.

A careful study should be made by means of borings, test pits, and test piles to determine the soil conditions and to decide on the type of foundations to be used. This study cannot be too carefully made, for upon the type of foundations used depends the stability of the structure, the speed of construction, and the cost of the work. I have in mind a case, in the construction of the new Delaware station of The Philadelphia Electric Company. This station is located on the Delaware River, on the site of the old Neafie and Levy shipyard. Core borings, made at regular and close intervals over the lot, showed rock in the form of a mica schist at an average depth of about forty feet below mean water. Above this were layers of sand, mud, silt and general river débris. Closer to the surface was an immense mass of timber in the form of individual sticks and arranged in cribs for shipways. After a careful study by the company's engineers, the architects and the constructors, it was decided to carry the foundations to rock. This was done by driving open circular caissons of steel sheet piling down to rock, then excavating and filling them with concrete. The wisdom of the method was early demonstrated by the speed and

ease with which the difficult work was done. In some places timber cribbing twelve feet thick and in a perfect state of preservation was driven through. The result was a great saving, both in time of construction and in the cost of this work.

Location on Site.

A study should be made of the location of the station on the property. This should be done in conjunction with the working out of the design and will be affected by the shape of the lot, flow of the stream, the manner in which fuel is received and the effect of the various locations on the cost of the plant. Recirculation of condensing water should be guarded against by proper arrangement of intake and discharge tunnels. Ease and speed of fuel handling into and out of storage must be considered, and also proper allowance made for electrical getaway, either underground or overhead, as required. Where, as is usually the case, the ultimate installation is to be made in steps covering a period of years, the size of the first step will have some bearing on the type of design and the location on the site. Investment should not be made for more construction, or for the installation of any more equipment than is required for the step under consideration unless the rate of growth is such that the need for the additional installation will be soon realized, or unless it can be provided at comparatively slight additional expense and the expense if deferred would be much greater. Very often the design can be workd out so that provision for future installation can be made at slight additional expense and the actual installation deferred until it is needed. I refer to such items as screen wells, condensing water tunnels, coal and ash handling equipment and bus bar and other electrical work. A so-called "Unit System" of design would seem to best meet this requirement.

Flexibility in Design.

The design should be sufficiently flexible to readily adapt itself to changes and advances in the art. We have seen rapid strides in the art of prime mover design in the past ten years and engineers have had their ingenuity taxed to harmonize additions to existing plants and to substitute larger units in the place of existing smaller ones. I have in mind a case where a large sum was spent to change existing steelwork and building structure to accommodate larger

boilers than were considered feasible when the building was constructed. Although we seem to have reached a pause in the increase of size of units, larger ones may come. We already have units of more than one cylinder arranged in tandem with one generator or in multiple with each cylinder driving a separate generator and we may come to still more modifications. Experiments have been conducted for some time on the mercury boiler and turbine in combination with a steam turbine and a trial commercial installation has been arranged for. Although not yet developed to a point where its general adoption is in sight, at the same time the efficiencies to be expected are such as to warrant its development and make future installation possible. While it is obviously impossible to make detail provision for such future development, the possibility of its installation should be recognized in the general development of the design.

Reliability of Service.

Reliability of service is the first requisite of a modern power station. It must be able and ready at all times to supply power in the amounts demanded. Increases in load must be anticipated by a careful study of the rate of growth and probable additions of load, and installation of equipment made in time to provide the capacity to care for load. There ought to be no limit to which we should go in insuring safety and continuity of service except that placed by the volume of the business. We can best provide for such service by the choice and arrangement of equipment that will be least liable to fail through accident or wear and by the installation of proper reserve capacity to take the load in case of failure and to permit the withdrawal from service of each piece of equipment at regular intervals for inspection and repair.

Continuity of service is affected by the amount of labor required in the operation of the equipment. This should be borne in mind in determining the length to which to go in installing labor-saving equipment. In case of labor trouble, the fewer men one has to replace in an emergency, the better is the continuity of service safeguarded. While not a controlling feature, this fact should not be lost sight of.

Ruggedness of design and number of parts subject to wear are important items in the selection of a unit. The conditions under which each piece of equipment will have to operate must be deter-

mined and choice made of the one that will best meet these conditions. In asking for quotations on equipment it is best to prepare a specification covering the essential requirements to be met and stating the minimum size of equipment that will be acceptable for the service. Sufficient data should be furnished by each manufacturer to permit of a complete comparison of the propositions received. These data should include, beside the price of the equipment, a detail description of the essential features of the design and the operating results to be expected under the stated load conditions.

DETERMINATION OF SIZE OF EQUIPMENT.

The determination of the size of equipment to accomplish a given result is an economic proposition dependent on certain fixed conditions.

Take, for example, a surface condensing equipment for a given turbogenerator. The steam to be condensed is a function of the vacuum which in turn depends upon the condensing surface and the amount and temperature of the condensing water. The temperature of the water varies from month to month and therefore the vacuum and amount of steam to be condensed for a given load on the turbine will vary. Conversely the amount of water required for a given vacuum will vary with the temperature of the water. The rate of heat transfer will vary as the tubes become dirty and will affect the vacuum. Load factor and station heat balance also affect the size of the condenser and the type of its auxiliaries, and it is for the engineers to decide how to best meet these conditions. Unless given certain stated conditions the manufacturer will naturally and properly assume conditions best suited to his equipment without regard to its effect on the subject as a whole.

Selection of the sizes of units will depend upon the character of load, peak load, rate of growth of load and load factor. For the smaller stations, the character of the load and shape of load curve influence the selection of units more than anything else. In this case the selection of the sizes and number of units will depend on the relation of peak to base load, duration of the minimum load, relative costs and economies of the units and the spare capacity required. This last should be equal to the capacity of the largest unit in the station. If the system be a small one with a single station and an ordinary light and power load, the first installation

would probably consist of two or three units. If two units are installed they would be of the same capacity, and each would be large enough to carry the peak load. If three units are installed, two would be of the same size, each of capacity sufficient for the day or base load. The third would be of less capacity or large enough to carry the night or minimum load and in conjunction with one of the larger units to carry the peak load. If the night or minimum load were sufficiently large, the three units might be the same size. As the load grew the sizes of units in each successive installation would be increased, the size of unit for each step being determined by the day or base load until the load has increased to a point where it equals or exceeds present maximum unit capacities or until nothing appreciable is to be gained in station economy by increasing the size of units. Beyond this point, and for the larger stations in which the load exceeds the present maximum unit capacities, the number and sizes of the units will be governed by operating practicability and flexibility.

Rate of growth of load has also considerable influence on the size of unit. A fast growing load means a rapid increase in station capacity to keep pace with the load. The smaller the size of each additional installation the shorter the intervals between the steps in the development of the plant. Larger units will cost more in total amount but less per kilowatt to install than the smaller ones and will increase the time until the next installation must be made. They mean a greater investment at each installation but fewer steps and a longer period between steps. They require fewer steps for a given development and the total cost for a given capacity will be less than with the smaller units. There will also be some operating economy to be gained on account of the greater efficiency of the larger units. The most economical size of installation to make, however, can only be determined by considering the investment and the operating economies in conjunction with the rate of growth of the load. The more rapid the growth the greater will be the increase in size of each succeeding unit up to the maximum.

Effect of Load Factor on Design.

I have previously made several references to load factor as affecting certain phases of power station design. Load factor is the starting point in the consideration of the economics of power

station design, and enters into practically every step from the choosing of the site down to the selection of the smaller pieces of equipment.

The output of a power station varies in accordance with the instantaneous demand. Power must be generated as it is used. It cannot be generated and stored during a period of low demand, as can gas, to be used to supplement production during a period of peak load, or at a time of minor interruption to production.

"Load factor" is the measure of the uniformity of production. It is defined as the ratio of the average rate of output to the maximum during a given length of time, and is stated as "daily load factor," "monthly load factor," or "yearly load factor," based on the period of time covered. The duration of the maximum demand is usually specified, such as "quarter hourly," "half hourly," or "hourly" demand. It indicates the plant's ability to carry the peak load over an appreciable period of time as distinguished from a momentary swing. Load factor may be applied to a plant as a whole or to any one generating unit.

The higher the load factor, or the more nearly continuous the output, the more are unit costs of production reduced through:

Increased operating efficiency of equipment.
Labor costs not rising in proportion to increased output.
Little, if any, increase in cost of superintendence and overhead expense.
Fixed charges being distributed over a greater output.

Load factor in itself is not a complete indication of operation conditions without the load curves from which it is obtained. Two load curves may give the same load factor and yet have essentially different characteristics. For instance, an intermittent load requiring full power for brief intervals throughout the day may give the same load factor, but impose very different operating conditions from another load of the same maximum demand in which the peaks were not so frequent and the base load uniform. This condition, however, is more liable to occur in a plant supplying power for an industry than in a plant supplying a community where the diversity is greater. An example of this fact is found in a plant recently installed for a factory in which the main load consisted of a number of large motors of from 600 h.p. to 700 h.p. each. These are operated intermittently for periods of about an hour each and not in accordance with any fixed schedule. The

result is a fluctuating load without any regularity requiring the plant at all times to be ready to take the maximum load, although operating most of the time at considerable less than maximum. The load factor for this plant may be better than one in which better economy is obtained for the reason that operating conditions are more constant over greater periods.

A high load factor means that more investment may be economically made in providing equipment of higher efficiency, the increased fixed charges being more than offset by the saving in operating expense. The more nearly continuous use of the equipment incident to the higher load factor would warrant the installation of fewer and larger units of greater economy, more liberal provision in condensing equipment, larger boilers run at lower and more economical ratings and possibly economizers or additional heating surfaces in boilers in the form of more and longer tubes in the path of the gases from furnace to uptake.

In making an analysis of load factor, especially in the case of a growing load, the length of service of a unit or a station at the load factor determined should be carefully estimated, in order to avoid serious error due to a change in load factor as the age of the equipment increases. Almost always a unit, or a station, is operated at its highest load factor during the few years immediately following its being put into service. At this time it usually represents the highest state of the art and is in the best of operating condition. As time passes, advances in the art produce better units, and even with the best of care the operating efficiency of the unit decreases, therefore when additions are made the base load and consequently higher load factor passes to the newer and more efficient equipment, and the older is used more and more for peak load or standby service. The load factor is consequently decreased and it is not possible to realize the economies of the high load factor operation. The fixed charges on the investment for the high load factor condition become a loss, compensated for in only a small way by the use of more economical equipment at the low load factor. Careful consideration and good judgment on the part of the engineer responsible for the design is required in order to make possible the maximum net return throughout the life of the equipment.

Load factor influences the choice of a station site by limiting the distance from the load it will be economical to go to obtain

adequate condensing water supply. The combining of individual systems into groups, such as is frequently done, is all in an effort to obtain greater economies through better load factor with consequent greater latitude in the selection of suitable station sites.

Load factor influences the selection of the size and type of equipment to be installed by fixing the extent of use of the equipment and consequently the economies to be attained. Generally speaking for the main units, the higher load factor warrants the installation of larger units up to the limits prescribed by the peak load and the existing state of the art.

The boiler plant is usually operated with respect to the station load rather than the loads on the various units.

The boiler room equipment to be installed will therefore be governed more by station load factor than by the load factor on any one unit. The number and size of boilers will depend upon the contemplated ultimate station capacity, the rating at which they will be run, and upon the sizes of the main units. Usually only one capacity of boiler is contemplated, although in some of the older stations that have passed through the rapid development period in main unit design, the capacity and type of boilers have been changed.

The ratings at which the boiler plant will run will depend upon the shape of the load curve and the station load factor. It is a question of comparing the fixed charges with the cost of operation and maintenance to be obtained from different numbers of boilers under the conditions imposed by the load factor. The higher the load factor the more boilers will it be economical to install that they may be run the more nearly at their most efficient rating. A low load factor usually means a shorter peak load, therefore, it is more economical to install less boiler capacity and increase the rating over the peak.

The selection of the type and details of design of the boiler depend upon its efficiencies at the ratings at which it will operate, the steam pressure, and the character of the feed water. A boiler in which the tube surface and baffling is arranged to give maximum effective passage of gases through the boiler with consequent greater heat absorption will be the most efficient type. A boiler requiring no stayed surfaces has decided advantages over others at the high pressures now coming into general use. A boiler with straight tubes is easier to keep clean and less liable to scale

and prime under poor feed water conditions than one with curved tubes.

The installation of economizers in conjunction with boilers is a question of boiler rating, station load factor, heat balance and cost of fuel. A high load factor or high fuel cost warrants the installation of more equipment to obtain greater economy. Economizers are merely additional heating surface placed in the path of the gases after they have passed over the boiler surface, and through which the feed water is passed on its way to the boiler. The ratio of economizer surface to boiler surface is based on so proportioning the heating surface between the two as to obtain the maximum heat absorption for a given cost. The performance of an economizer is dependent on the temperature of the entering feed water, the temperature of the flue gases leaving the boiler and the amount of surface. Temperature of feed water is determined by the station heat balance, which is influenced in the case of stations having steel tube economizers by the necessity of keeping the entering temperature high enough to preclude pitting of the tubes. The temperature of the gases entering the economizer is dependent on the type of boiler, arrangement of baffling and the rating at which it is running. The amount of economizer surface depends on load factor and the cost of fuel. The amount of the heat rejected in the flue gases depends on the load factor and a high fuel cost increases the value of the heat thus rejected and makes it worth that much more to reclaim them. The amount of surface it is economical to install will depend on the cost of the additional equipment, its operating cost and the value of the heat reclaimed. In making this determination it is well to cover a considerable interval of time and to take into consideration the probability of fluctuations in the cost of fuel. Fixed charges on the additional investment will remain the same, but a decrease in fuel cost or a lowering of the load factor will mean less value of the heat reclaimed and the installation may be a net loss. This is especially true at the present time when prices are on the down side of the peak and when it is reasonable to expect that installation costs will be less in the future. A compromise might be to make provision in the design but postpone the installation until some future date, when prices are more stabilized and the economies to be obtained give promise of being permanent.

Selection of Auxiliary Equipment.

The selection of other power station equipment such as heaters, pumps, exciters, etc., depends on reliability and flexibility and on load factor through its effect on the station heat balance. A high load factor requires more nearly continuous operation of auxiliaries and gives less chance for making minor repairs during off peak periods. The reliability must therefore be greater.

Heat Balance.

The production of electrical energy in a steam power station is the result of a combined number of thermal operations and conversions of energy. Chief among these are the generation of steam by the combustion of the fuel and its utilization by the main units in the production of electrical energy. In addition there are the operations of the auxiliary equipment necessary for the support and continuance of the main operations, and for the recovering of the energy rejected by the equipment.

Heat balance is an analysis of the thermal processes taking place in a plant from the combustion of the fuel in the furnace to the production of electrical energy by the generator. It indicates the distribution of the energy produced by combustion among the different pieces of equipment accounting for that portion which is usefully employed and for what is thrown away. It is the power station energy balance sheet. Its careful study is therefore necessary if the most economical installation is to be made and many trial balances may be required before the answer is obtained.

Operating Pressures and Temperatures.

Among the first things to fix upon in the working out of a heat balance, and in fact, in the design of a station, are the operating steam pressure and temperature.

The theoretical efficiency of a steam turbine is the ratio of the difference between the total heats of the initial and final conditions to the total heat of the initial condition minus the heat of the liquid at the final condition. The lower limit is expressed by the exhaust steam temperature and is fixed by the vacuum in the condenser. This is dependent on the temperature of the condensing water and the amount of tube surface. The temperature of the water fixes the maximum vacuum possible and the load factor determines the economical amount of tube surface to install. The practical lower

limit to the temperature can be said to have been reached, and it is only by increasing the upper limit that betterment of efficiency can be obtained.

Theoretically for any given initial temperature the greater thermal efficiency is obtained with high pressure saturated steam. But two principal reasons prevent the maximum theoretical efficiency from being realized. First, the design and construction of equipment and piping have not yet reached the point to withstand the pressures of very high temperature saturated steam generation; and second, saturated steam, while theoretically the most efficient, is in actual use subject to losses through condensation, greater friction, etc., that render its use less economical. It therefore becomes necessary in practice to effect a compromise, adopting a working pressure that is practical from an operating and construction standpoint and superheating the steam to attain the maximum feasible temperature range and reduce losses due to friction and condensation to a minimum. Two hundred pounds was looked upon as a reasonable and economical working pressure eight years ago. Today we have a number of plants operating at 250 lb., several at from 275 lb. to 300 lb., and two or three at over 300 lb. Present designs of boilers are adaptable to pressures up to 400 lb. without radical changes, and turbine manufacturers state they can design units for any pressure the boilers can develop. Pressures and temperatures existing today do not cause particular troubles with steam piping if care is exercised in the design of the system and in the choice of materials. Ample provision should be made for expansion and flexibility between anchorage points by means of easy bends and turns. Superheated steam has caused the adoption of cast or wrought steel for all pipe flanges and of cast steel for fittings and valve bodies. Monel metal or nickel bronze is used for valve seats, discs and trimmings. Velocities of steam have been increased in turbine plants until in some cases we find them as high as ten to twelve thousand feet a minute.

Existing designs of equipment permit the use of steam temperatures up to about 650° or 700° F., without serious trouble. Above this temperature, however, present designs begin to give trouble.

Except at high ratings this temperature is difficult to obtain in the ordinary boiler setting with the superheater located at the top

of the first pass or in the second pass. In the most recent designs of boilers of the B. & W. type with high tube banks, the sections are being divided and the superheater placed in the first pass part way down from the top of the tube bank. This insures the maximum temperature of superheat at lower rating.

The present state of the art therefore may be said to permit of the economical adoption of pressures not exceeding 350 lb. pressure and temperatures up to 700° F. Conservative design would place the present limit at about 300 lb. and 650° F. There are stations projected abroad in which the steam conditions are higher than have been attempted here. The equipment, however, is of special design and construction, costing more to build and install, and made economical only by the higher price of fuel.

Effect of Type of Auxiliary Drive on Heat Balance.

There should always be sufficient duplication of auxiliary equipment to insure reliability of service at all times and to give sufficient flexibility for economical operation. Spare auxiliary equipment, or equivalent, is as essential as reserve main units.

Methods of drive for the auxiliary equipment vary from "all steam" to "all electric" with variations and combinations of the two. Each combination furnishes a heat balance showing the performance of the equipment under the load conditions and indicating the most efficient points of operation, together with the energy utilized and that thrown away. Comparison of the heat balances of the various combinations will indicate the most economical one to use.

The great proportion of energy rejected in the generation of electrical power occurs in three processes:

1. In the circulating water used for condensing the steam from the main units,
2. In the flue gases from the boilers, and
3. In the exhaust from the steam-driven auxiliary units.

The energy rejected in the circulating water represents the greater part of the total heat generated and is not recoverable. The energy in the flue gases can be recovered in part, and in so far as it is economical to do so by the use of economizers for heating the feed water or the air for combustion. That in the exhaust

from the auxiliaries can be recovered by heating the feed water or at certain loads by use in the lower stages of the main unit.

Electric energy used to drive auxiliary equipment can be obtained either from the main unit, from an auxiliary unit installed for the purpose, or from both. Where the auxiliary drives are both steam and electrical, the current is generally supplied by the main unit. Where the drive is all electrical the current is usually taken from an auxiliary unit or "house turbine." In this case the house turbine exhausts into a heater condenser of the jet type where the steam mixes with and heats the boiler feed water. In this manner the heat rejected in the exhaust steam is recovered. Recent designs for all electric drive contemplate a general duplication of auxiliary equipment driving part with current from a house turbine and part from the main unit. In this case part of the steam for heating the feed water is extracted from the main unit and condensed in an auxiliary condenser using condensate for the purpose. This method insures reliability of service by having two independent sources of power for drive, but introduces some complications on the electrical side by the duplication of switching equipment and buses, necessary to give the flexibility of operation desired. The extraction of steam from the main unit does not materially affect the economy of the main unit as the lower stages of the unit are less efficient at full load due to crowding of the steam. Extracting a portion of this steam permits more efficient use of the remainder in the lower stages and the energy of the steam extracted is all returned to the system through the heating of the feed water.

The final temperature to which the feed water should be heated and therefore the selection of the proper heat balance depends upon the use of economizers. Without economizers the temperature will be kept as near 212° as possible. With economizers it will probably be more economical to keep the feed temperature lower than 212° to permit of greater heat absorption by the economizer.

Choice of Fuel.

Fuel is the greatest item of expense (exclusive of fixed charges) in the generation of power, its cost in a modern central power station seldom being less than eighty per cent. of the cost of operation and maintenance. The choice of the fuel, therefore,

has a decided effect both on the boiler room equipment and on the station economy. On account of its great quantity and wide distribution coal is, of course, the most used fuel. Oil has been used for fuel for a number of years principally in territories close to the oil fields, and more recently in localities more remote from the coal fields and where there is water transportation. Natural gas is used in some localities as are hogged fuel, and other combustible residue from various manufacturing processes. But coal may be called the standard fuel, and any station that is built should be so designed and constructed that coal-burning equipment can be installed without radical changes, no matter if some other form of fuel may prove more economical for the time being. By so doing one does not put himself under the obligation to use any fuel longer than it is economically possible to do so.

Coal.

Coal is mined in practically every section of the country except the New England States and every locality may be said therefore to be within reasonable distance of a supply of some kind. The kind and quality of coal, however, vary greatly with the section and even within the section in which it is mined, from the high heat value bituminous coals of the West Virginia and Pennsylvania regions to the lignites of the southwest and northwest.

The choice of the kind of coal to use will depend on the available supply, the heat value and the distance it must be transported. For the stations that are nearer the mines and where the freight charge is not such a great proportion of the total cost, the lower and cheaper grades of fuel will often be the most economical in spite of the decreased efficiency. For the more remote stations, however, the freight charge becomes the greater part of the cost and therefore it will be more advantageous to use a higher heat value coal with its better efficiency of combustion. This is particularly true of the New England States which have no developed fuel supply within their own limits and for whose use coal must be transported over long distances. Here only the better grades of bituminous coal from West Virginia or Pennsylvania are used.

The equipment for burning the coal varies in type with the grade to be used. For the high grade bituminous coals or coals of the coking type, the underfeed type of stoker is used. These stokers permit of burning continuously large amounts of coal per

hour per square foot of grate, and in conjunction with the forced draft which is required, enable the boilers to be operated at high ratings. They are flexible in their operation, permitting the operation of the boilers to follow closely the fluctuations in the load. They consume little coal when banked and can be brought up from a banked condition and put on the line in a very short time. In recent large installations the lengths of the stokers have been increased and clinker grinders substituted for the usual dump plates. These features, together with the addition of auxiliary blast ducts admitting air to the back of the stoker, permit the practically complete combustion of the fuel, thus greatly decreasing the combustible in the ash and adding to the efficiency of the plant.

For the lower grade coals, with high ash content, high volatility, and usually a high percentage of sulphur, chain grate stokers have been used. The earlier types of these stokers were natural draft, but the demand for higher ratings has led to the rapid development of traveling grates using forced draft. The Coxe stoker is of this type and has been used successfully for a number of years, principally in the anthracite region. It has proved equally successful when burning the semi-bituminous and lignite coals of the Middle and Far West. Other makes of forced draft chain grate stokers are being developed and recent installations indicate their success in meeting the operating requirements of the installation. The underfeed stoker has also invaded the semi-bituminous and lignite field with some fair success. The most success seems to have been obtained with stokers having some positive ram action to help the feed of the coal down the grate and to break up any heavy clinker that may form on the grate.

Anthracite coal has usually been used for domestic purposes. The smaller sizes, such as barley and buckwheat, are available for making steam, and the forced draft chain grate has also made usable the vast culm banks thrown aside in former years as unfit for use. Fine coal from the washeries deposited in the beds of creeks and rivers in the anthracite regions is being dredged out in great quantities and reclaimed for use as fuel. This great supply of anthracite, unfit for domestic use, but capable of being burned under boilers, has developed a market for itself and is being used in localities well outside the anthracite field. Existing installations have demonstrated the ability of the forced draft chain grate to burn these types of fuel with sufficient grate speed and combus-

tion rate to develop boiler ratings of well over 200 per cent. continuously. Before making any decision to use this fuel outside the anthracite field, a careful comparison should be made of the efficiencies as compared with other and better grades of fuel that may be available. The source of the supply and its continuity should be well established. Dredging for river bed coal is interfered with during cold weather and larger reserve stocks will have to be carried at the plant to insure continuity of service. And lastly, in order to make sure against possibility of loss, the cost of the additional installation for anthracite burning equipment should be considered as written off during the life of the anthracite contract. This puts the burden of proof heavily up to the anthracite coal man, but it is the only safe method where the type of fuel is special and inability to renew a contract for any cause will mean radical changes in equipment.

Pulverized Coal.

Pulverized coal has been attracting a great deal of attention lately and several installations are now in successful commercial operation. The preparation of pulverized coal has been pretty thoroughly worked out through its use in the cement industry, but its combustion under boilers is of comparatively recent development. The earlier installations were made under existing boilers whose settings were not designed for pulverized coal, and limitations were thus imposed which precluded the best operating conditions and results being obtained. Several installations designed and proportioned for the burning of pulverized coal are being built and put into operation that give promise of successful and economical operation. Tests are now being conducted on a modern boiler installation at Rivermines, Missouri, and a complete new power station of 40,000 kw. initial installation, using pulverized coal, was placed in commercial operation at Milwaukee on December 23, 1920. These should furnish interesting and valuable data on the subject and have an important bearing on the future of the system.

The principal field for pulverized coal lies in the low-grade coals that can, with great difficulty, if at all, be burned on existing stoker equipment. Whether or not the small increase in efficiency in burning the better grades of coal in pulverized form is warranted, depends upon the size of the installation and the load factor.

Oil.

Oil has been used for fuel in some localities for a number of years. These have been principally in the oil fields or in places where there was cheap water transportation as compared with high freight rates on relatively poor coal. The older installations used steam atomizing burners operating on natural draft. Difficulties in properly mixing of oil and air produced a long flame and required so much combustion space that the amount of oil it was possible to burn under a boiler limited its rating to around 200 per cent. From two to three per cent. of the steam generated is required for atomization.

The mechanical atomizing oil burner has been used for some time on shipboard, but only within the past eighteen months has it been adapted to land service. With this type of burner, using forced draft, it has been possible to burn 1300 lb. of oil per hour in one burner. The proper proportioning and mixing of oil and air in the burner requires less combustion space than with steam atomization and permits operating the boiler at higher ratings and with but slight drop in efficiency at the higher ratings.

There have been a number of recent installations of oil-burning equipment in stations along the Atlantic coast, extending as far north as the New England States. These installations have been made possible economically by the high price and scarcity of coal, and by the number of new refineries erected for the production of gasolene by the "topping process." This process leaves an oil of around 18,000 B.t.u. per pound which is available for burning under boilers. It has been a case of the "early bird getting the worm," for later installations that were contemplated have not been made because of the inability to obtain oil at a price that will compare with coal or under a contract for any length of time or that will guarantee a reliable supply.

Comparison of Coal and Oil.

In making a comparison of the relative economy of oil and coal the same remarks apply as for anthracite coal; that is, in the cost of the oil must be figured the charges necessary to wipe out the investment for oil-burning and storage equipment and of

changing back to coal at the end of the contract. These are proper charges against the use of oil and must be made if the comparison is to be complete. At the end of the contract this method leaves one free, either to undertake a second contract at a higher price, if the price of coal has not increased, or to effect a larger saving if the price of oil has not gone up.

II. MECHANICAL FEATURES OF DESIGN.

The design of the power station structure and the arrangement of equipment do not in themselves have much direct effect on station economy, although they do have an important influence on the amount of labor required for operation and on the cost of maintenance.

There are more ways than one to solve the problem and local conditions often play such an important part that to attempt to generalize and say that one type of arrangement is better than another, especially without all the facts, would only invite controversy without hope of agreement. There are certain facts and principles, however, applying to the general subject which can be stated without risk of an argument.

Divisions and General Arrangement of Plant.

The arrangement of a steam power station naturally divides itself into three parts:

1. The boilerroom or that portion in which is located the equipment to produce steam,
2. The turbine room or that portion in which the steam is used to produce electrical energy, and
3. The electrical bay or switch house, being that portion in which the electrical energy is received from the generator, and distributed to the feeders going to different parts of the system.

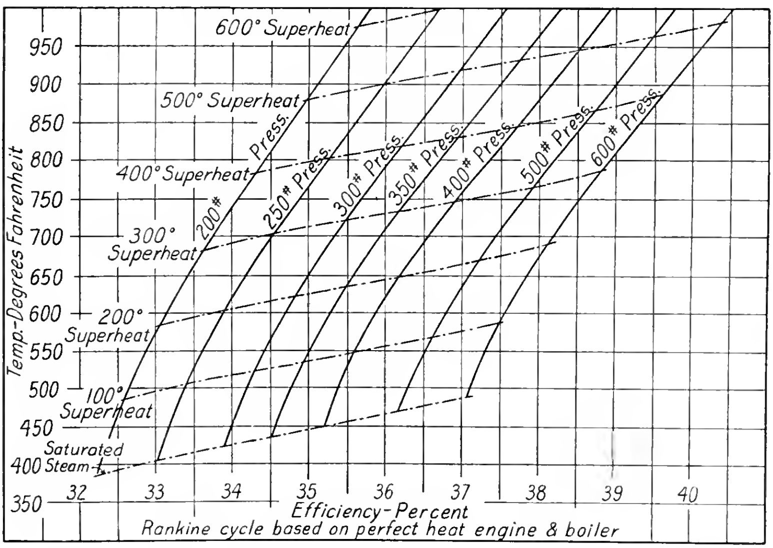
For simplicity of operation and arrangement the three parts usually are placed side by side with the turbine room in the middle. Ordinarily only one division wall separates the boiler and turbine rooms. The electrical bay is sometimes placed with a single division wall between it and the turbine room, and sometimes in a separate building or switch house. There are a few instances where the electrical bay is at the end of the turbine room

and some where the switching equipment is above the turbine room. Local conditions and other special reasons have usually dictated these arrangements.

Operating Floors.

Each portion of the plant will have different operating levels or floors (Fig. 2). Thus in the boiler room we have the ash room, boiler floor and sometimes the economizer floor levels. In the turbine room, the condenser floor and turbine floor or platform, and in the electrical bay, we have reactor floor, bus floor, switch floor levels, etc.

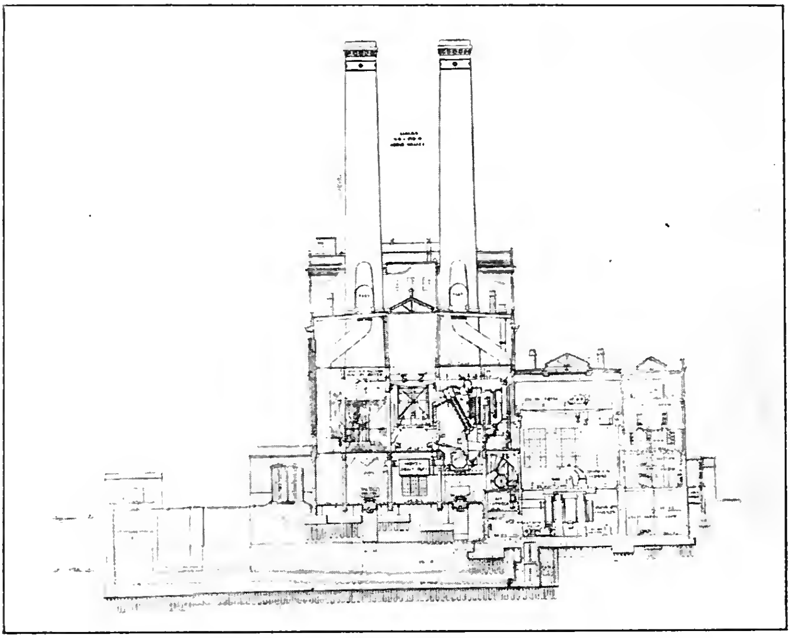
FIG. 1.



Theoretical efficiencies of Rankine Cycle computed from Temperature-Entropy diagrams.

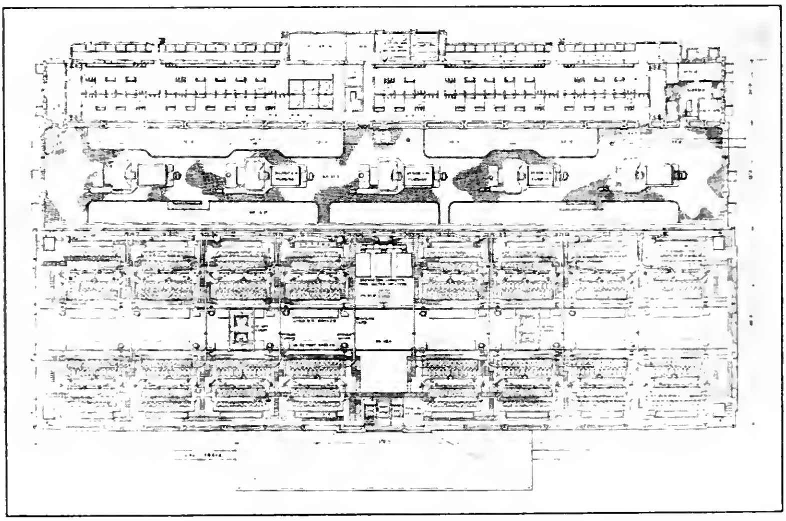
The number of floors or operating levels in a plant should be kept to a minimum, and as far as possible the different operating levels of adjacent portions be the same. Thus the condenser floor and ash room floor levels should be the same and the boiler room and turbine floor or platform. Local conditions sometimes make this possible, as for instance, in stations located on streams where great differences in level between high and low water are encountered and where condenser pumps must be placed so as to operate at low water. This occurs in some places in New England

FIG. 2.



Cross section—South Meadow Station. The Hartford Electric Light Company.

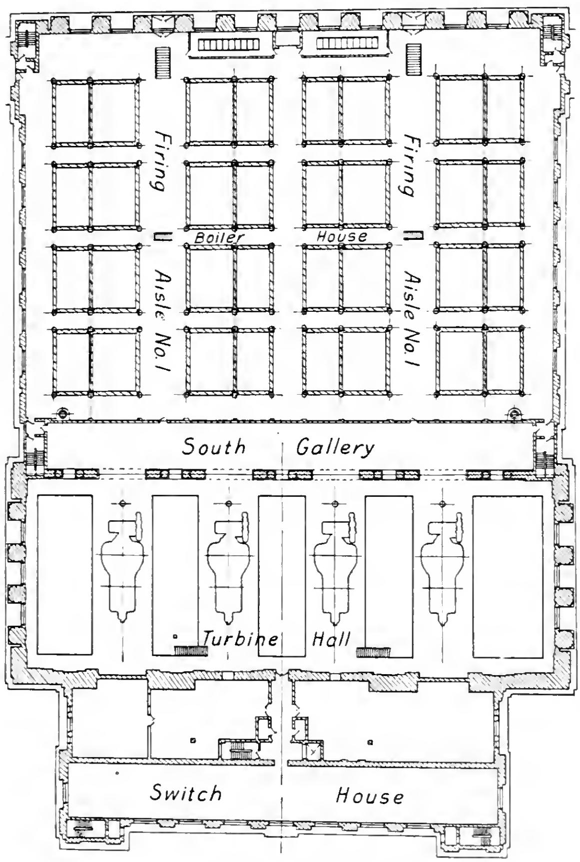
FIG. 3.



Plan—Boiler room and turbine platform, South Meadow Station. The Hartford Electric Light Company.

where there are differences in water level of 30 feet (Fig. 2), and in the Middle West where differences in level vary from about 30 feet around Pittsburgh to 65 feet at Cincinnati. These conditions create special and difficult problems in arrangement of

FIG. 4.



Plan—Chester Station. The Philadelphia Electric Company.

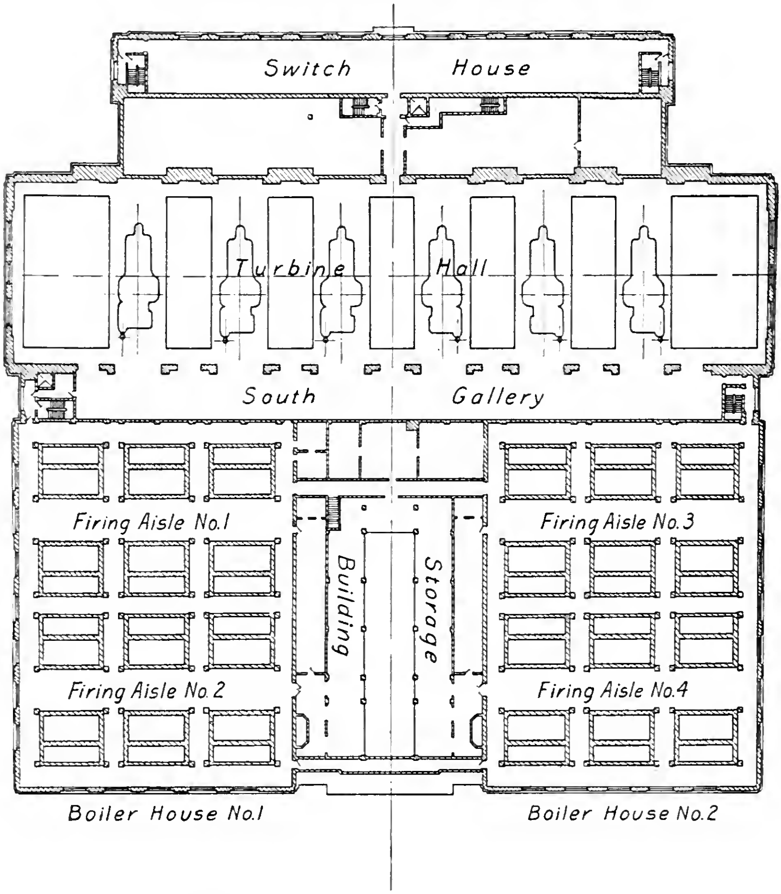
equipment and design of foundations, they cost more to erect and force a compromise with more desirable arrangements.

Turbine Room Arrangement.

Turbine units are arranged with their shafts either lengthwise (Fig. 3) with or crosswise (Figs. 4 and 5) to the turbine room.

When arranged lengthwise they are usually placed in a single row, although the two-row arrangement has been used in several stations, having been first done to permit of the installation of a maximum of capacity in a station originally designed for smaller vertical units.

FIG. 5.



Plan—Delaware Station. The Philadelphia Electric Company.

Boiler Room Arrangement.

Arrangement of the boiler room is usually along one of two lines, either with the firing aisles parallel with (Fig. 3) or at right angles to the turbine room (Fig. 4).

The right angle boiler room is ordinarily used in a station arranged on a unit system, that is, when each unit has its own boilers and auxiliaries complete.

This arrangement divides the boiler room into a number of different firing aisles, usually half as many as there are main units. Each aisle has its complete installation of coal and ash handling equipment and each row of boilers has its ducts, flues, chimneys, etc., distinct from the other rows. The arrangement splits the boiler room operation into as many sections as there are aisles.

In the parallel boiler room (Fig. 3) the boilers are in rows parallel with the turbine room, with usually only one firing aisle, unless the boilers are double stokered. This arrangement utilizes the same coal and ash handling system for all the boilers and does not split the operation into separate groups. On the other hand, it makes a longer boiler room, which usually extends beyond the ends of the turbine room unless the turbines are placed lengthwise, or if crosswise, are spaced farther apart than actually required.

A compromise between the two is employed in the new Delaware Station of The Philadelphia Electric Company (Fig. 5) in which there are four rows of six boilers each, with two firing aisles parallel with the turbine room. This gives four boilers in a line at right angles to the turbine room. The piping is so arranged that each line of four boilers ordinarily serves one unit, which is placed with its shaft crosswise to the turbine room.

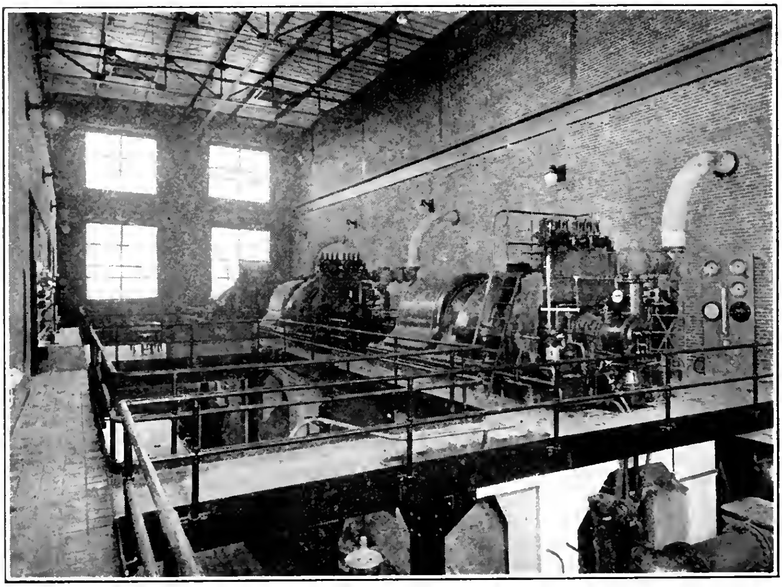
As far as ground area occupied is concerned, there is not much difference between the two arrangements, what there is, however, generally slightly favoring the parallel arrangement. Boilers are usually fired from one end only, as enough grate area and a sufficient number of retorts can usually be installed on one end to develop continuously ratings of over 200 per cent. In a few cases, however, boilers are fired from both ends. This is the case at Detroit where the boilers are of such large nominal rating that sufficient grate area cannot be installed at one end and therefore it is necessary to stoker from both ends to obtain even the moderate ratings at which these boilers are run. In other stations such as at Buffalo, and in the Springdale Station of the West Penn Power Company, where very high ratings are carried continuously, it is necessary to fire from both ends.

Heights between floors and different operating levels should be ample to allow the installation of the equipment without crowding, and headroom for proper operation (Fig. 2).

Lighting.

Sufficiency of light, both natural and artificial, and accessibility of equipment are factors that help toward proper operation and lower maintenance, and should be given careful consideration. To this end it is becoming more and more general practice to make the turbine room floor of area sufficient only for the proper operation of the equipment located thereon and leaving the rest

FIG. 6.



Pittsburgh Plate Glass Company, Kokomo, Ind. Turbine room, looking southwest.

of the space open to the condenser floor (Fig. 3). This permits natural light to reach all parts of the condenser floor and allows the use of the turbine room crane for dismantling and erecting most of the auxiliary equipment (Figs. 6 and 7).

Accessibility.

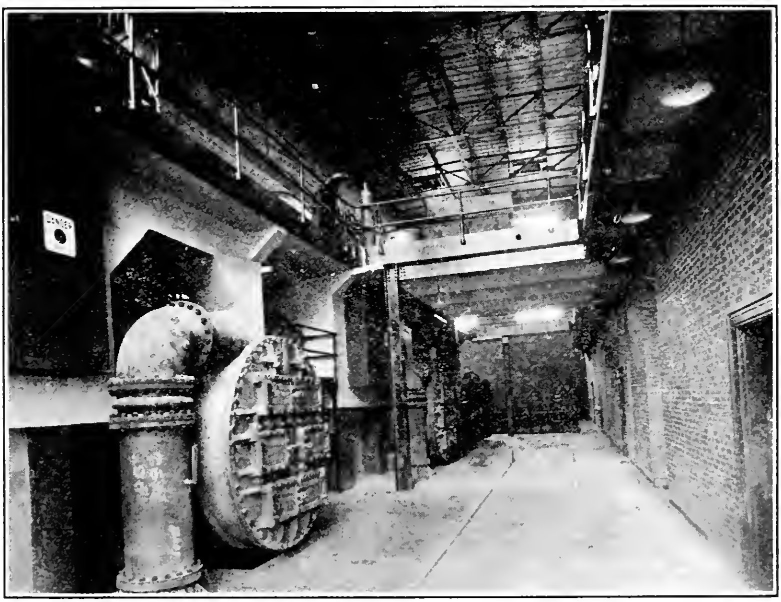
Providing easy access to various equipment and parts of equipment by means of stairways and walkways are an aid to operation, especially in the boiler room. Combination passenger and freight elevators are frequently installed in the boiler room and electrical bay. The height of a modern power station is frequently more

than that of a six-story building, so that these provisions are not in the nature of a luxury but are a real necessity.

Framework.

Most stations have a steel framework with brick walls and concrete floors, either plain or covered with tile. This is generally considered the best combination from the standpoint of rapid and economical construction, ease in hanging and erecting piping

FIG. 7.



Pittsburgh Plate Glass Company, Kokomo, Ind. Condenser room, looking northwest.

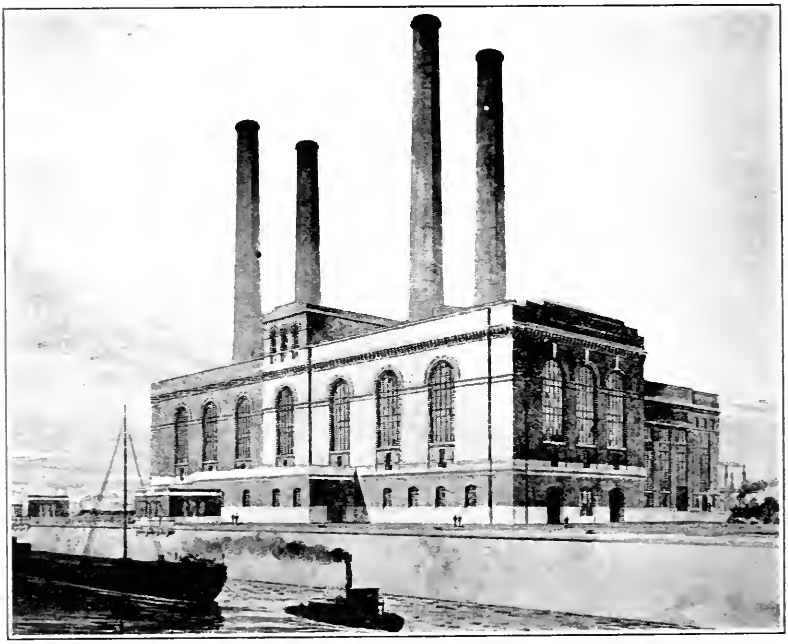
and in making changes in, and additions to, the structure. There are cases, however, where the reinforced concrete type of building has been used with economy and satisfaction, as in the northwest, where lumber and cement are plentiful and steel has to be transported across the country. The newest station of your local company has been built of reinforced concrete for a special reason. The building laws of your city require the fireproofing of all steel members of the building structure. This means encasing all beams and columns in concrete. Also the station was designed

and construction started during the war when steel could be had only with great difficulty. These circumstances led to the adoption of the reinforced concrete building and the design, as worked out by the engineers and architect, has been well adapted to its purpose.

Architectural Treatment.

The extent to which architectural design and embellishment

FIG. 8.



General elevation—South Meadow Station. The Hartford Electric Light Company.

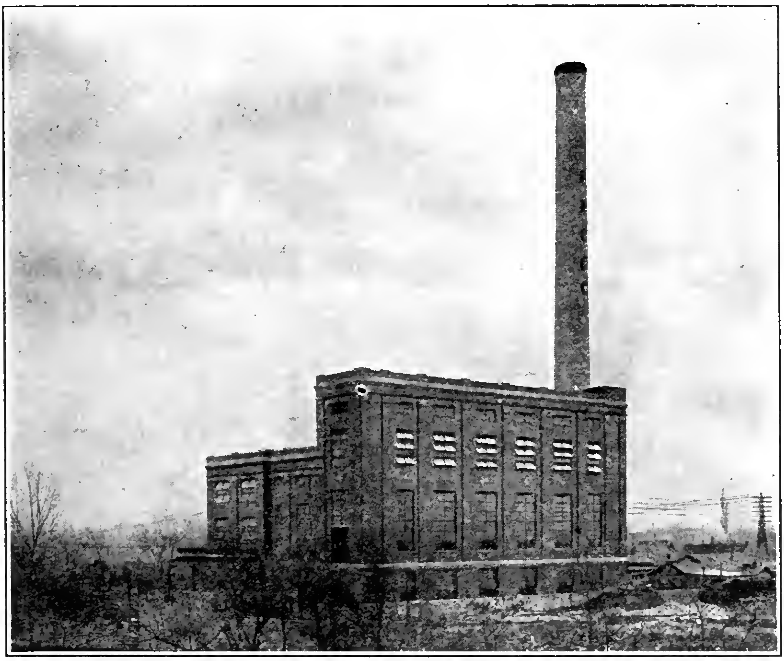
should be carried will depend on the character of the neighborhood in which the station is located and the value which is placed on appearance as a matter of public policy or as an aid to obtaining business and in promoting cleanliness.

A station built in a locality of a better sort requires treatment that will not detract from the surroundings. Its appearance should also be such as to impress a prospective large user of power with its stability and convince him that the service he will get will be

absolutely reliable. On the other hand, there is the danger to be avoided that he will consider the station too ornate and that an undue portion of the money he will pay for power will go to meet fixed charges on unwarranted investment. With careful study, however, a simple and adequate treatment can be worked out (Figs. 8 and 9).

In regard to the interior treatment, these same remarks apply.

FIG. 9.



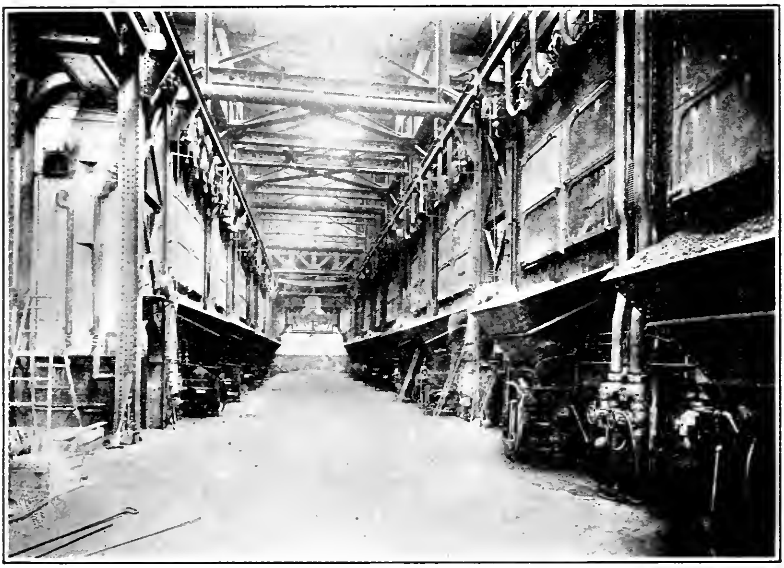
Pittsburgh Plate Glass Company, Kokomo, Ind. Power station, looking southeast.

Here, however, is involved the question of neatness and light as an aid to cleanliness and maintenance. In the turbine room, light-colored walls aid the light in reaching remote places where dirt might be allowed to collect or where equipment is located that might be neglected if the place were dark. Whether enamelled, or other light-colored brick be used or the walls be painted, will depend on the relative cost and the value placed on this feature. Painted walls require being done over every few years; brick walls

require cleaning down at regular intervals to give maximum effect.

A double or suspended ceiling improves the looks of the turbine room but is not usually justified for this reason alone. It does, however, provide an air space between the roof and the turbine room and with proper ventilation is a great aid in preventing roof condensation in winter. This has been a great source of trouble, especially in the older stations, and much study is being given to the subject. The elimination of the causes of moisture, such as

FIG. 10.



New Bedford Gas and Edison Light Company. Boiler room, looking east.

steam seals exhausting into the room, leaky joints and open blows, will do as much toward diminishing this trouble as anything else. Gypsum is being used more and more for roofs with a view toward decreasing condensation.

Floors are usually of tile or cement finish, treated with some form of hardener to prevent dust and wear. Tile is often used in the turbine room and condenser floor. It is easy to keep clean, adds to the appearance of the room, and its cost is not prohibitive.

In the boiler room the equipment and the operations are of

such nature as to make any architectural treatment difficult and unnecessary. Care should be exercised in the design, however, to reduce to a minimum places where dirt can collect. I refer to spaces in and around columns, gusset plates projecting above floors, ledges and other places where articles, such as waste, can be carelessly left or thrown. A little study during the period of design can usually greatly reduce the number of these places without increase in cost of construction.

Design of structure should be such that maintenance is not only possible but easy. Exposed structural and other steelwork should be accessible for repainting and steelwork in damp or wet places such as the ash room should be protected from corrosive action.

Light in the boiler room is as important as in the turbine room. Windows should be ample and properly placed to give light where it is needed. Care should be taken not to overdo, however, as windows to be effective require cleaning, and fewer windows properly cleaned are as effective as many more that are not kept clean. The use of skylights over the boiler aisles, along the sides of the coal bunker if it is over the aisles, or if the bunker be central, over the whole aisle, aids in getting light over the boilers and along the aisles (Fig. 10).

Stacks and Flues.

In large modern stations, stacks are usually superimposed on steelwork above the boilers to save the space in the building that would be required to run them down to foundations on the ground. At first all the superimposed stacks were of steel, but of late concrete stacks are being built superimposed. The concrete stack weighs somewhat more than a steel stack, but it has to be lined only a small proportion of its height and requires practically no maintenance while steel stacks require painting every two to three years.

Flues are now usually placed on the roof of the boiler room to reduce headroom over the boilers.

Ventilation and Heating.

Ventilation and heating of the station are being given more careful thought with each new design. Buses, reactors, transformers and electrical switching equipment give off considerable

heat. They are usually located in rooms closed from the outside air and require artificial ventilation to provide a constant circulation of air to remove the heat generated. The air for this purpose is usually washed to remove dust and dirt and to cool it in summer. In winter the air is usually tempered after washing to prevent the rooms from becoming excessively cold. Circulation is usually by forced draft or exhaust fans, or both.

Turbine room ventilation is often combined with the generator air washing and cooling system. In this case the washers usually draw air from the room. In the summer time with the doors and windows open this draws the outside air into the turbine room and into the generator cooling system. The heated air is either discharged outside the building, into the ash room where the forced draft fans can take it, or in the older units out of the top of the generator, whence it rises toward the roof and out through ventilators or louvres. In the winter time the air is usually discharged into the turbine room to help keep the place warm. In one station all the air is washed before coming into the turbine room and the generators draw air direct from the room and discharge into a mezzanine floor over the ash room, where it is taken by the forced draft fans.

The ventilation and heating of the turbine room has a direct bearing on the amount of roof condensation that will occur in winter. In one station now under construction, after careful study, a system was worked out and is being installed, which it is expected will prevent roof condensation. The roof trusses are arranged for a suspended ceiling, and by a system of ventilators there will be a circulation of air between the ceiling and the roof. The generator air washers are used in the scheme about as previously described, and in addition a separate fan will deliver sufficient washed and warmed air into the room to produce at all times a slight positive pressure in the turbine room. What air leakage there is will therefore be outwards and no cold air will be drawn into the room.

In the boiler room the air required for combustion is many times that which may be discharged by the generators into the room, and in practically all stations this air is drawn from the boiler room and ash room. The amount is sufficient to change the air in these rooms many times an hour, making a very cold

place in winter time and exposing pipes to danger from freezing. This condition should be given serious study in new stations with a view to providing means for taking this air from the outside in the winter time.

The boiler room should be closed from the turbine room, both as an aid to keeping the turbine room warm in winter and to prevent dust and dirt from getting into the turbine room. Cleanliness can be promoted by closing in the coal bunker from the remainder of the boiler room to prevent coal dust raised while filling the bunker from permeating into other parts of the building.

Coal and Ash Handling.

The handling of coal and ashes is usually a special problem. Methods of unloading, storing and conveying depend on the way coal is received at the station, the size of the plant and the amount stored. The amount stored depends on the plant output, load factor, the distance from the coal supply and the space available. Elaborate handling and storage systems are expensive and warranted only in large installations. Some of the largest stations store and reclaim all their coal by means of locomotive cranes. This method has great flexibility and requires less expensive equipment, but is slower and consequently takes more labor than a complete automatic equipment. In the large stations located on salt water, coal is usually unloaded directly from barges into storage or into the power station bunkers. The two largest stations in Boston have ground adjacent to them for coal storage and fairly elaborate storage and reclaiming systems are installed. In New York where real estate adjacent to the station is not available and in the two new stations of your local company, coal is conveyed directly into the station bunkers. This requires bunkers of larger capacity than with outside storage or storage of coal remote from the station.

Overhead storage in bunkers is either provided over the boiler aisles with individual spouts to the stoker hoppers, or the bunker is located at the ends or centres of the aisles and coal taken from it and conveyed to the stoker hoppers by traveling larries. Sometimes larries are used instead of the individual spouts when the bunkers are over the aisles. The larry is coming more and more into general use. It has the advantage of making the whole

storage space available for any one boiler instead of only the portion immediately over it as in the case of individual spouts. It keeps the boiler aisle free from spouts and chutes which have to be removed when it is desired to open the doors on the boiler fronts for inspection and cleaning. It is a reliable piece of equipment and danger of shutdown due to accident is remote. In the larger stations, two or more larries are provided, and danger of shutdown is eliminated.

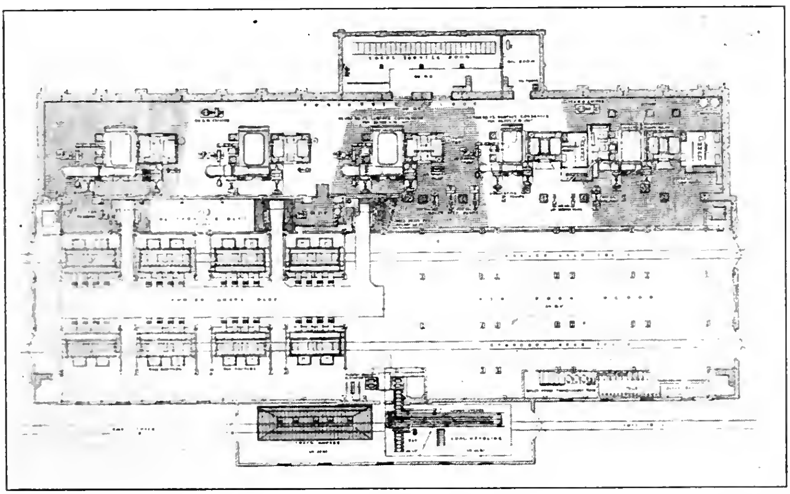
Close record should be kept of the coal consumed and for this reason it should be weighed as it is used. In some stations coal is weighed as it is being conveyed to the bunkers and a check on the station consumption made at intervals of a week or a month. To do this it is necessary to estimate the amount in the bunkers at the end of each interval. This gives a quite accurate measurement over a period of time, an error in one measurement being compensated for at the next. This method does not, however, give the close and detail check that is given when the coal is weighed as it is fed to the stoker hopper. This can best be given by the weigh larry, or by individual automatic scales placed in the downspouts to the stoker hoppers where this method of feed is used. The detail check on the coal burned is of great value in indicating the hour-to-hour or day-to-day performance of the boilers and shows up inefficient operation in time to correct it immediately. It also has a psychological effect on the boiler room labor who are more liable to realize the importance of careful operation when they see so much stress placed on the accurate accounting for the coal used. It shows the coal burned by each shift and properly worked a friendly spirit of rivalry can be engendered that will work toward improving the station economy.

A simple laboratory for the testing of fuel used and of samples of feed water is usually warranted in the larger stations. This affords means of quickly, accurately, and frequently checking up these important items of operation.

The handling of ashes is always a nasty and vexing problem that is seldom satisfactorily solved. In the large stations where the facilities permit it, ashes are being dumped from the hoppers direct into railroad cars. This is a very satisfactory and wholesale way of handling the problem. In the smaller stations a motor

truck serves the same purpose. In order not to require too frequent dumping, hoppers should have capacity enough to hold a day's accumulation of ashes. They are usually directly over the ash tracks. In stations where facilities do not permit of handling in this manner, industrial railway cars drawn by storage battery or gasolene locomotives are usually employed. These take the ashes out of the building where they are disposed of on the lot, or elevated into overhead bunkers to be drawn off into railroad cars, trucks, or barges.

FIG. 11.



Plan—Condenser and ash room floor, South Meadow Station. The Hartford Electric Light Company.

Importance of Simplicity in Arrangement.

Simplicity of arrangement is an important aid to good operation. Auxiliaries for one main unit should be arranged similar to those of other units (Fig. 11). Piping systems, both steam and water, should be as simple as it is possible to make them and still properly perform their intended functions. Duplication of lines to minimize chances of shutdown often defeats its purpose through too great complication. Careful study in the design of a simple system, with proper number and location of valves, can often accomplish as much toward safeguarding operation as a great duplication of systems. Piping, after making due allowance for

flexibility and expansion, should be as direct as possible, with lines and valves similarly placed for similar pieces of equipment.

Automatic Regulation.

Devices for the automatic regulation of various equipment and phases of operation are being more and more employed. They vary the operations of auxiliary equipment, the rate of supply of fuel and water, and the conditions of draft in accordance with the load. They aid in decreasing the operating cost by practically eliminating manual manipulation, and by adjusting the conditions to the load more closely than is possible with hand regulation. To make them of maximum effect, however, they require intelligence on the part of the operating force and a knowledge of the principles of their operation.

Conveniences for Operating Force.

Provision of offices and places for the preparation and storage of records, facilities for the comfort and cleanliness of employes, and of devices for the prevention of accident to equipment and men is an aid toward proper and more efficient operation. The larger stations and a number of the smaller ones have offices and rooms both in the boiler room and turbine room, where the men in operating charge can go over the charts and records and prepare the station logs and reports.

Locker and toilet rooms, clean and well ventilated, with adequate facilities for bathing and washing up after work is done, are essential parts of a modern station. Promoting cleanliness in person aids in the maintenance of general cleanliness, and in securing and keeping a desirable class of labor. Many large stations now have restaurants connected with them where employes can obtain hot food and drink for their meals.

Accident Prevention.

Attention should be given to providing against accident to men and equipment. Guards should be placed around gears and chains, belts and other dangerous moving pieces of equipment. Grease cups should be brought out where they can be reached without danger. Curbs and railings should be placed around openings. In general, a careful study of the accident hazards should be made both during the design and after the installation is complete.

III. OPERATION OF PLANT.

To obtain maximum economy a steam power station should be operated practically under a condition of continuous test. To do this the performance of the various equipment, and of the plant as a whole, must be closely followed, and instruments should be installed to indicate and record the results obtained and the conditions affecting the operation.

The instruments should be of such type and in sufficient number to give indication of faulty operation and a continuous record of the results obtained.

Care should be taken that not only are all necessary instruments installed, but that unnecessary ones are omitted, as these give records that are not vital to the operation and by adding to the data obtained, tend to confuse the interpretation of the useful records. These instruments should be read at frequent and regular intervals and recorded on a station log sheet. This station log or operating record should be so arranged as to facilitate analysis of the results obtained. Related figures should be brought together to show the effect of variables under control of the station operators, such as loading, vacuum maintained, draft, flue gas temperature, boiler rating, fuel used, etc. The results should be worked up promptly at the close of each watch by members of the station force so that the men themselves may thoroughly understand the figures and profit by the comparisons shown. A report should be made up each day giving the average conditions obtaining and the results obtained, including peak load, kilowatt hours and fuel per kilowatt hour.

To maintain the desired dependability and efficiency in power station equipment, it is necessary to place such equipment under a system of definitely scheduled inspection and maintenance. By this means every piece of apparatus is thoroughly inspected at regular intervals and potential causes of trouble discovered and remedied before great damage is done. In order that maximum benefit may be derived from the experience gained in making these inspections and repairs, the records of this work should be systematically entered in a concisely indexed log book so arranged as to provide a convenient usable reference for those immediately responsible for the upkeep of the equipment.

Of almost equal importance with the actual operation and maintenance is the installation of a system of cost records. Every

month a complete report should be made up from these records, giving the operating results obtained and the station costs arranged to show clearly the cost of any phase of operation or maintenance both in total amount and on a unit basis. Only by such means can the economy and cost of operation be studied and kept within reasonable limits.

The Preparation of Sodamid and Sodium Cyanamid from Lead-Sodium Alloy.—In a thesis presented to the Technical High-school at Karlsruhe, WILLIAM LEIBROCK presents numerous data on the manufacture of important sodium products. He reviews at considerable length the many efforts that have made to secure economical and convenient electrolytic procedures for preparing sodium, the initial procedure, being as is well known, due to Davy, more than a century ago. Serious difficulties arise in the conduct of such methods on the large scale, and many patents have been taken for improvements in the apparatus and in other respects. Leibrock directed his experiments along the line originally indicated by Faraday, that of absorbing the liberated sodium in a heavier metal in the liquid form as the kathode. After many trials, success was achieved with lead which formed an alloy containing a notable proportion of sodium. For the analysis of this alloy, the investigator devised the following method:

A sample with surface carefully cleaned (3 to 15 grams according to the richness in sodium) is weighed rapidly and placed in a casserole with from two to five volumes of mercury. The formation of an amalgam begins at once, and the reaction may be hastened by gentle warming. When all the lead alloy has dissolved, the mixture is allowed to cool and then covered with water. According to the richness in sodium, the reaction will be more or less violent, and finally the whole of the sodium will have been dissolved. The mixture is heated on the water-bath until the surface of the metallic mass is smooth, which indicates the termination of the solution of the sodium. Allowing the mixture to cool, the amount of sodium hydroxide formed can be determined by titration, in the casserole without regard to the presence of the lead amalgam. The latter can be subsequently distilled by which the mercury can be recovered.

The methods for obtaining sodamid and sodium cyanamid from this sodium-lead alloy are described in the essay. Leibrock states that the sodamid prepared thus is less explosive than that prepared by the customary methods, and that, while the exact cause of the explosiveness of this compound is not clearly known, it has been pointed out that it has a marked power of dissolving metallic sodium. The sodamid prepared from lead alloy has, so far as analysis shows, only one difference from the ordinary compound. It contains less free sodium, and this may be possibly the cause of the lower explosibility.

H. L.

CHARACTERISTICS OF THE ELECTRIC LOCOMOTIVE.*

BY

N. W. STORER

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THE rapid growth of the United States in population and in wealth has been made possible only through its vast network of railways. Our railways, and practically the entire inland transportation system, have grown up around the steam locomotive. To this picturesque personification of power then, we owe our national greatness. However, there have been many evidences in the last few years which indicate that our railways need more power, and a different kind of power, than the steam locomotive can supply.

The rapid growth of the country, stimulated as it was by the railways, has imposed most severe requirements on them. There has been an unceasing demand from the traffic department for more power, for larger and still larger locomotives. The steam locomotive designers have risen to the occasion magnificently, and the modern steam locomotive is so much larger and more efficient than the locomotive of thirty years ago that a comparison between them is scarcely possible. It would seem, however, that the limit to the capacity of the steam locomotive has been closely approached, if it has not already been reached; and where greater capacity is required, another type of motive power must be used. The other type of power, in the shape of the electric locomotive, is in the field prepared to take an increasing share of the load from the boilers and cylinders of the steam locomotive; to take the load where the inherent limitations of the steam locomotive make it unequal to the demands upon it or its use undesirable or impracticable.

The far-seeing railway operator is studying the subject of electrification more seriously than ever before, and he confidently looks to the electric locomotive to help him out of many difficulties. He starts with the desire for more power and with

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, April 14, 1921.

the idea that he will substitute the electric locomotive whose power can be made anything that is desired for the steam engine whose power is limited by the boiler it carries. While there is no question as to the ability of the electric locomotive in this respect, he finally realizes that electrification requires practically a revolution in operating methods before all of its advantages can be secured.

Many of the old ideas that have grown up around the steam locomotive will have to be modified or abandoned and new methods introduced. The length of engine divisions, ruling grades, distribution of coal and watering stations, dispatching, the tonnage and speed of trains, the design of stations and terminals, have all hinged around the steam locomotive. This revolution will not have to take place all at once—it will be rather a gradual evolution of new methods that will be worked up by the more progressive operators, as the advantages and possibilities of electrification develop before them.

Among the many features that will become evident to the operating man making a close study of the subject of electrification are the following:

1. The power that can be applied to a train is in no way limited by the size of the individual motive power unit. The electric locomotive derives its power from a central power station which may carry the entire railway load and a large industrial load at the same time. Theoretically, the locomotive can draw the maximum amount of power that can be utilized at one point in the train. Whatever may be the size or capacity of the individual motive power unit, it places no limit on the amount of power that can be controlled from one cab, since two or three, or half a dozen if need be, of these units may be coupled together and operated on the multiple unit system like a train of suburban or subway cars. A locomotive may then be an aggregation of motor trucks with a single engineer's compartment. Practically the only limit to the tractive effort that can be controlled from this one point is the strength of the drawbars. Drawbar pull, however, is not the only way in which the greater power is developed; speed accounts for fully as much, and it will soon appear that the highest economical speed for traffic movement can be met by the electric freight locomotive; this may be two or three times as great as that of the steam locomotive. This is

particularly apparent on the mountain grades where the heaviest freight trains when pulled by steam locomotives make from 7 to 10 miles per hour, while the same trains, or heavier ones pulled by electric locomotives, run from 14 to 20 miles per hour. The electric locomotive makes it possible to operate freight trains at practically any desired speed. From this it can be seen that freight trains can more closely approximate passenger train schedules and thus greatly increase the track capacity.

In passenger service it is probable that it will not be considered economical to operate trains at much higher maximum speeds than are attained with steam locomotives. However, it will be possible to operate at a more uniform speed and with fewer delays. Heavy grades can be covered at as high speed as is safe or economical, so that if desired a higher schedule speed can be maintained with the same maximum speed as at present.

2. The length of the division on the railroad will be no longer limited by the locomotive. Electric locomotives make the run daily over the entire electrified section of the Chicago, Milwaukee & St. Paul Railway, between Avery and Harlowton, a distance of 440 miles, and are repeating this trip over and over until 4000 miles or more have been covered before the locomotive goes to the shop for anything but the casual light inspection it receives at ends of runs. There is no question but that the locomotive division could be much longer than 440 miles if it were convenient or desirable to make it so. If the large ocean liners can keep their engines running for a couple of weeks without stop, and Pullman cars can run thousands of miles, there is no reason why electric locomotives cannot operate equally well, and take equally long runs. Under the conditions of operation on the Chicago, Milwaukee & St. Paul Railway, even with only two passenger trains each way per day, one locomotive has made more than 11,000 miles in a single month. With the schedule arranged to suit, this mileage might easily be from 15,000 to 20,000 miles per month. This, of course, means a great reduction in the number of locomotives required. A record for a continuous 24-hour run of 766 miles has already been reached by the passenger locomotives on this road.

3. Electrification permits radical changes in terminals, due partly to the absence of smoke, dirt and noise, and very greatly

to the use of multiple unit car equipments for the suburban traffic. The absence of the smoke and dirt results in a change in the entire character of the neighborhood surrounding the railroad and its station. The railway is free to take full advantage of its aerial rights in the construction of hotels, office buildings, warehouses, etc., over the tracks, which, with steam locomotives, must be left open. What this one feature alone means in a congested centre like the Chicago district, for instance, where there are 4500 miles of steam railroad track in operation, it needs no words to tell. Wherever the value of real estate is high, the land covered by the railroad is very valuable and its use for building purposes can be made a source of revenue to the railway, which will go far towards paying the cost of the electrification.

The absence of smoke and dirt makes it safe and desirable to enter the city in a subway, and to have the tracks on two or more levels with a corresponding increase in capacity of the station site. This in the future may, in fact, be the only possible answer for the increase in needed capacity.

The use of multiple unit equipments makes large increase in the terminal capacity, especially where it is a stub-end terminal like that at Broad Street, Philadelphia, by decreasing the number of idle movements in the terminal which are necessary with the steam locomotive but are not required at all for the electric. All of these advantages are familiar to everyone who is interested in the subject.

A considerable improvement in terminals will also be made in the handling of freight. The electric switcher lends itself to any desired arrangement of terminal and yards. It has proven its value in the great Harlem River yards of the New York, New Haven & Hartford Railway where the switchers remain in continuous service a month or more at a time with no more attention than the crew can give them.

4. The advantage in the use of the electric locomotive for long tunnels is obvious. This has been recognized for many years, and many long tunnels that were objectionable with steam locomotives have been electrified with the best of results. The Simplon Tunnel, constructed under the great mountain range between Switzerland and Italy was based wholly upon electrical operation. In fact, it would probably be impossible to operate

a tunnel 12 miles long in any other way at this time. This characteristic of the electric locomotive will undoubtedly be taken advantage of hereafter in eliminating many long and expensive mountain grades by tunnelling through the mountains. There seems to be no reason why tunnels of much greater length should not be used.

5. Electrification obviously means conservation in fuel. Just how great this conservation will be is a mooted question. Some enthusiastic electrical exponents claim it will save two-thirds of the fuel that is now used by the steam locomotive. Some steam locomotive enthusiasts, on the other hand, deny that anything approaching this saving can be effected, basing their statements on a comparison with engines of the latest design and the best practice. Undoubtedly neither is wholly right, but it cannot be disputed that the consumption of fuel is attended with every refinement continuously in a modern power house, and that this can never be hoped for when this responsibility rests upon the performance of each of the thousands of locomotive firemen on steam locomotives. Bearing this in mind, it seems certain that, on the average, an electrified railway with modern steam power houses would not use more than one-half of the fuel that would be required for the railway under steam operation.

6. Another thing electrification means which is of vastly more importance to the management is the greater effectiveness of labor. This follows from the greater capacity which can be secured from the railroad machine.

It would seem that, just as it is possible for the housewife to save herself an enormous amount of drudgery in the everyday duties of keeping house by the adoption of the innumerable electrical devices which are now offered on every hand, so it will be possible for the railway operator to improve labor conditions by the proper use of the most efficient and reliable of all modern servants—electricity.

7. Last but not least among the things which are to be mentioned as following electrification of a railroad is increased reliability of the motive power. In every case where electric power has supplanted steam, this has been inevitably attended with improvement in regularity and reliability of train movement.

What are the characteristics of the electric locomotive that make it so desirable; that fit it so admirably for railway service?

1. Its maximum tractive effort is from two to four times its normal continuous running tractive effort. This depends for the most part on the coefficient of adhesion which is used for the normal tractive effort. This may vary anywhere from 5 per cent. to 20 per cent. of the weight on drivers. Of course, where the normal tractive effort is 20 per cent. of the weight on drivers, it would be impossible to secure more than double the normal. Ordinarily a coefficient at normal tractive effort of 16⅔ per cent. will not be able to give more than 100 per cent. above normal as a maximum, but where, as is usually the case, the normal tractive effort requires only from 10 per cent. to 15 per cent. adhesion, it is possible to develop as much as three times the normal. This compares very advantageously with the steam locomotive whose maximum tractive effort or given horsepower rating is comparatively close to the normal running. It means a great deal in the operation of the locomotive; it makes it comparatively easy to start its normal train in the worst position and also to start it very quickly without jerk. Everyone knows who rides on our steam trains that a heavy passenger train is usually started with a jerk. The reason for this is simply that the steam locomotive at the head of the train must jerk it if it is to start at all, because its maximum tractive effort is so close to that required for pulling the train after it is started that it has little margin. The locomotive may be amply large to pull the train at high speeds, but it cannot start it without a heavy jerk. The electric locomotive, on the other hand, can start with a steadily increasing tractive effort until the train begins to move, and the maximum tractive effort can be maintained until full voltage is applied to the motor.

2. The capacity of the electric locomotive is limited by the heating in the motors. The necessity with an electric locomotive is to keep the temperature of the parts down, which is just the reverse of that of the steam locomotive. For this reason, the electric locomotive can easily develop considerably greater power in cold weather than in warm weather. Here, again, it is just the reverse of the steam locomotive.

3. Practically all of the wearing parts of the electric locomotive have normally a long life. Therefore, all that is needed to keep the locomotive on the road is to secure proper lubrication, keep the bolts tight, brakes adjusted, and to give an occasional inspection to insure that nothing abnormal has taken place in

the equipment. This is the secret of the great mileage which is possible with the electric locomotive; it explains why the locomotive is ready for service so large a part of the time; it is the reason that only one-half or one-third as many electric locomotives are required for a given service as would be required for steam operation; it explains why the round-houses and inspection forces can be reduced to such a small limit; why the intermediate division points are eliminated; it gives the reason for the great reliability of the electric locomotive.

The foregoing are some of the most prominent general characteristics of the electric locomotive. It must be understood however, that there are many other characteristics, depending on the specific type of locomotive that is under consideration; in other words, on the system which is adopted for the electrification. These characteristics are apparent chiefly in the speed and tractive effort curves. The three types of locomotives which are in use in this country to-day are, first, direct-current with series wound motors; second, single-phase locomotives with commutator type motors having series characteristics; third, constant-speed locomotives fed either from a single-phase trolley by means of phase converters or from double trolleys carrying three-phase current.

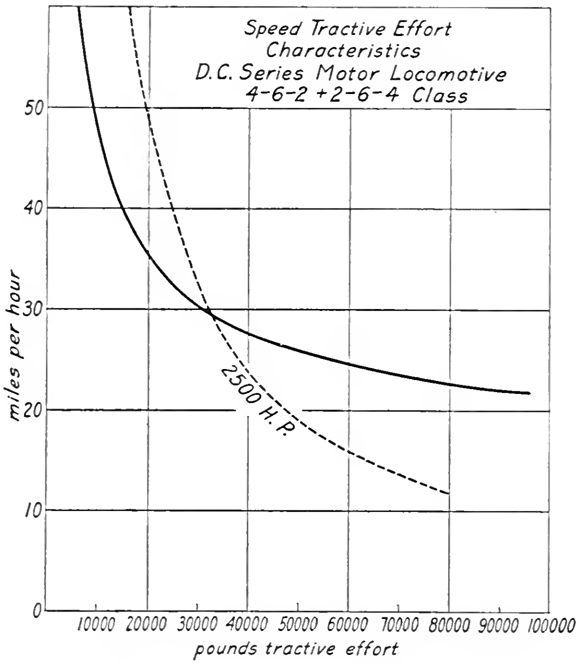
DIRECT-CURRENT LOCOMOTIVE.

The series wound motor is the one which is in practically universal service the world over where direct current is used. Its characteristics are especially suited for railway service, since the speed curve falls rapidly as the tractive effort increases, which gives the best characteristic for dividing the load, especially where a considerable number of driving units are operating in the same train. It also permits the motor to handle a much heavier load or a normal load on much heavier grade than would be possible if the speed did not fall with the increase in tractive effort.

It gives, in a way, the same effect as the shifting of gears on an automobile enables it to exert an unusual amount of effort with a relatively small engine. The method is not the same, but the result obtained is similar. The solid curve on Fig. 1 shows the performance of the direct-current series motor. Thus, it can be seen that this slowing down of the speed with increased effort relieves, to a certain extent, the whole electrical supply system—the trolley, the transmission lines, and the generating

units—from the peak loads caused by starting heavy trains or by hauling over heavy grades. When lighter grades or level track is reached, the characteristics of the series motor cause it to speed up very rapidly, as shown by the shape of the curve, so that full advantage is taken of the falling off of the load by increasing the speed. While running over a varying profile, it can be seen that the speed of the motor will vary much the same

FIG. 1.

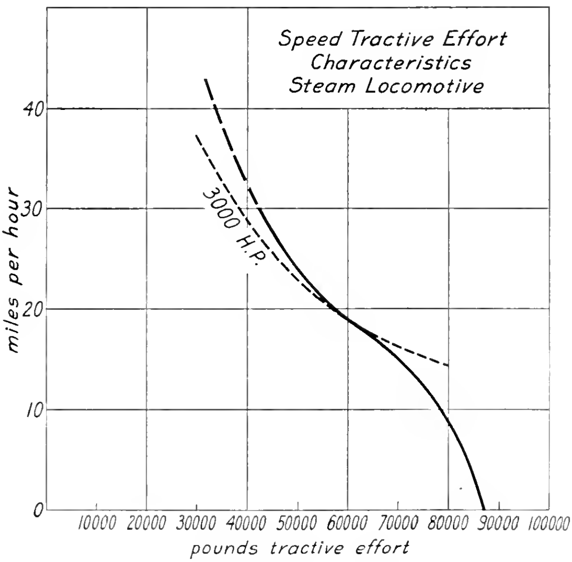


as that obtained with a steam locomotive. Speeds will be considerably reduced on heavy upgrades, but may be quite high on level track, and as high as the roadbed will permit on downgrades. A train running behind time may be pushed to the limit at every opportunity, and the time made up.

On all of the figures in dotted lines are plotted a series of constant horsepower curves. That is, the speed and tractive effort read from any point on a given curve will produce a constant horsepower. The direct-current motor curves at the higher speeds resemble these constant horsepower curves, and run very

nearly parallel to them. On Fig. 2 is plotted a curve showing the speed-tractive-effort characteristics of a modern steam locomotive. This curve has the desirable faculty of following the shape of the constant horsepower curves very closely. On the other hand, however, it does not have the same desirable characteristic at the heavier tractive efforts which is evident on the electric motor curve, namely, that of rapidly increasing its pulling power as the load increases. The torque of a steam locomotive

FIG. 2.



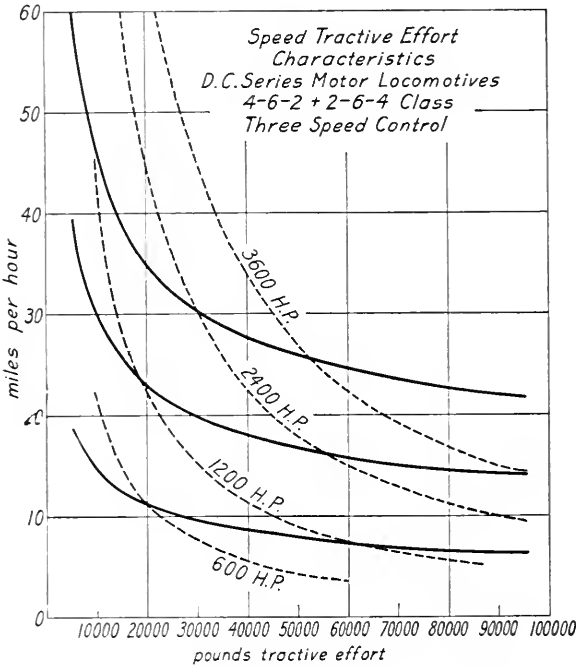
is limited definitely by the ability of the boiler to supply steam and the cylinders to utilize the steam. This is shown by the rapid falling off of the curve when this point is reached.

These curves then illustrate the advantage of the series motor characteristics which approach the constant horsepower curve over a certain portion, and at the same time permit of exerting very high tractive efforts when necessary.

With the series motor, the only means of controlling the speed is by varying the voltage on the motor. This may be accomplished by inserting resistance in series with the motor, but this is very inefficient, and cannot be used for other than acceleration. The common method used for obtaining this speed

control with direct-current motors is to connect the motors in different series and series-parallel combinations. Fig. 3 shows three speeds obtained by connecting the motors: First, all in series so as to give one-third voltage and speed; second, in series-parallel to give two-thirds voltage and speed; and third, in parallel to give full voltage and speed. This method covers the speed range fairly

FIG. 3.



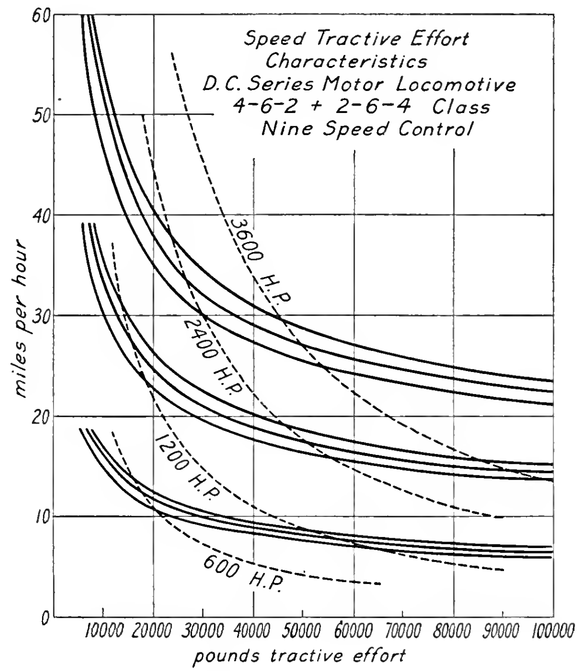
completely. Fig. 4 shows the addition of six more running speeds, making nine in all. These additional speed curves are obtained by varying the effective turns on the motor field. With the use of these "field control" points, the range in speed is very effectively covered. This set of curves shows the characteristics obtained on the new 3000-volt, direct-current passenger locomotives built for the Chicago, Milwaukee & St. Paul Railway.

ALTERNATING-CURRENT LOCOMOTIVES.

Fig. 5 shows the speed torque characteristics of an alternating-current series motor locomotive. This curve is somewhat more

steep than a direct-current series motor curve, and more nearly approaches the constant horsepower curve shown by the dotted lines on the same figure. This type of motor does not, however, have the ability to produce the very high starting torques which it is possible to obtain from the direct-current motor, because of certain commutator limitations when drawing heavy currents. On the other hand, the speed control on this motor is very easily and efficiently obtained by varying the voltage applied to the

FIG. 4.

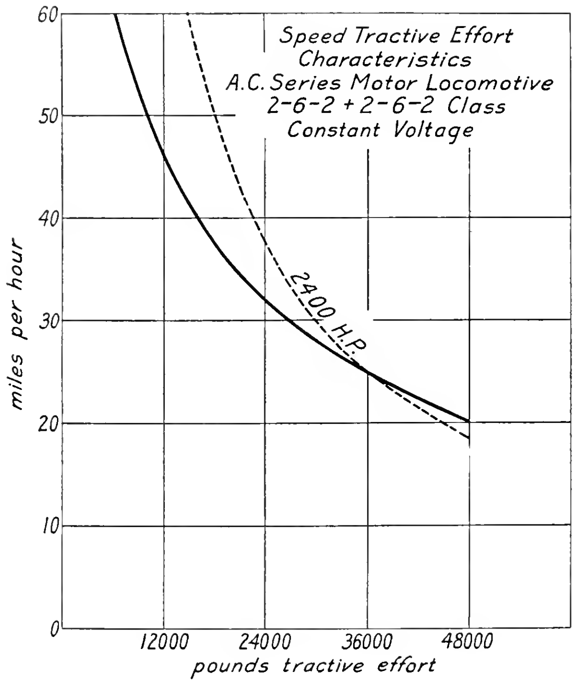


motors. Power is furnished from different taps on the transformer, and the different speeds obtained as shown on Fig. 6, without in any way altering the grouping of the motors. These curves show the speed control obtained on the latest type passenger locomotive built for the New York, New Haven & Hartford Railroad.

The other motor used for railway work is the alternating-current induction motor. This motor is essentially a constant-speed motor. Its characteristics are shown on Fig. 7 and are

quite different from either of the other two motors discussed. Other running speeds can be obtained with this motor by varying the number of poles, and by cascade connections, but it is rarely practicable to obtain more than two running speeds. The curves shown give two speeds, one at 14 miles per hour, and the other at 28 miles per hour. These speeds are as obtained on the Norfolk & Western freight locomotives. Acceleration is obtained by

FIG. 5.

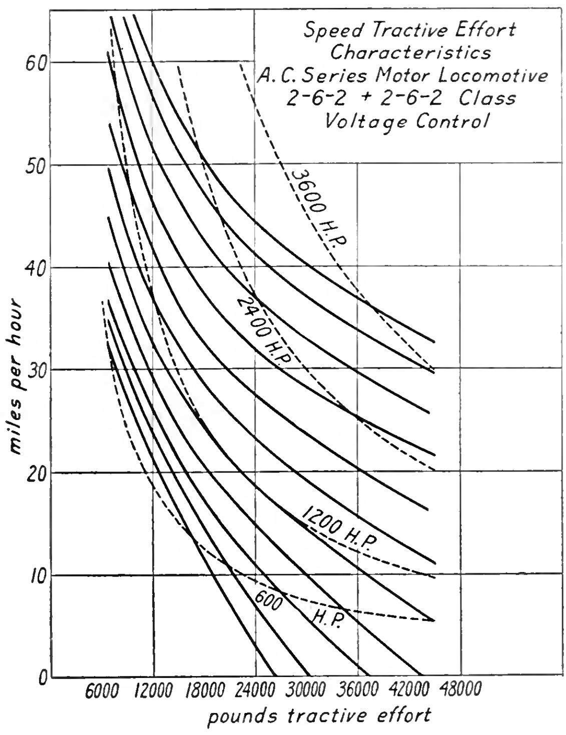


varying the resistance in the secondary of the motor, but these resistance points cannot be used as running points. This type of motor is capable of producing very heavy starting torques, and of carrying very heavy loads, but on heavy loads, the speed is maintained at practically a constant value, and the power required increases practically with the tractive effort. It is necessary, therefore, to have a motor of greater capacity than with the series motor, in order to take care of the peak loads. Some care is also necessary when operating more than one locomotive of this type in the same train, or even with different motors on the

same locomotive, to balance the load between them and not overload one motor or one locomotive with more than its proportion of load. A slight difference in wheel diameter may cause considerable overloading, unless special means are used for balancing.

There has been considerable discussion among railroad men as to the advantage and disadvantage of the constant-speed characteristic. The claim is made by some that it is a decided advantage

FIG. 6.

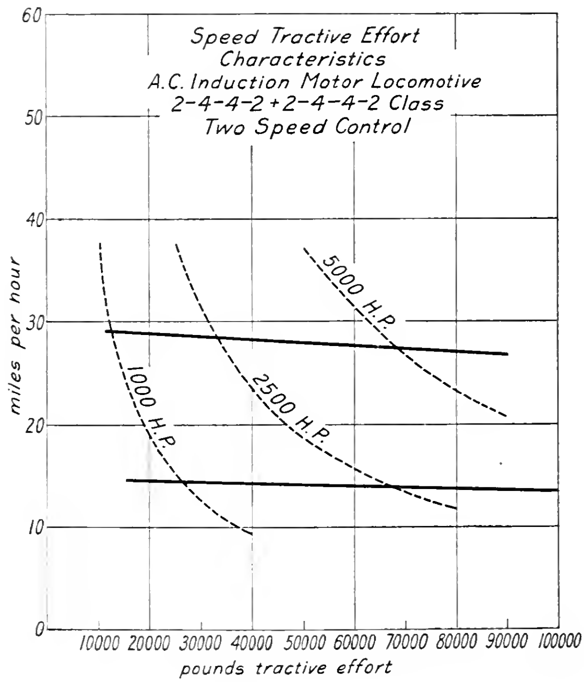


to be able to start a train from one terminal and know that, barring break-down, it will run at the same speed up hill and down, and arrive at the other terminal at a certain definite time. On the other hand, it is claimed that the ability of the series motor to take advantage of every opportunity for making speed is a very desirable characteristic, when it is necessary to make up time. A series-type locomotive of a given rating will always be

able to make a better schedule than a constant-speed locomotive of the same rating.

Fig. 8 gives a set of curves showing the characteristics of the various motors and a steam locomotive. These curves are plotted in percentages so as to be comparative.

FIG. 7.



REGENERATION.

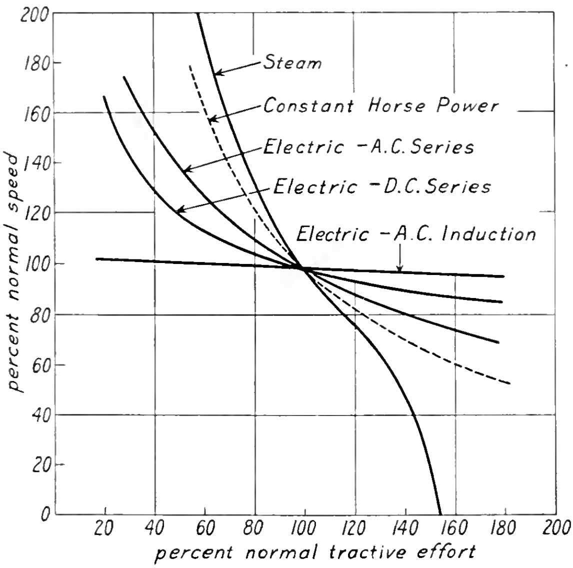
Regeneration, or regenerative braking, is another characteristic of the electric locomotive, the advantages of which cannot be overemphasized. While this feature makes it possible to reclaim some of the energy stored in a train when it reaches the top of a heavy grade and starts to go down, this saving in power does not by any means represent the full or most important benefit to be derived from it. Perhaps the most important advantage, and the one which will appeal most forcibly to the railway operating man, is the ease of control and safety provided by this

form of braking, as well as the reduction in wear on brake-shoes and tires.

Regenerative braking may be obtained on any of the three classes of locomotives previously mentioned. The methods of providing for this are, of course, different.

In the constant-speed locomotive, with induction motors, regeneration is automatic. When the locomotive, in running

FIG. 8.



down grade, reaches a speed above synchronism, the motors act as generators excited from the line. In this respect the constant-speed locomotive has a great advantage, but the speed is fixed.

The series-type of motor, whether alternating-current or direct-current requires excitation from some separate source, and therefore involves some additional apparatus on the locomotive.

Direct-current motors may be excited from a line-driven motor generator set, or an axle-driven generator; or, one or more of the main motors may be used as exciters for the others. Regenerative braking has been thoroughly tried out on the Chicago, Milwaukee & St. Paul Railway and is very successful. It permits

operation on the down grades at any desired speed and holds the train without surge or jar. The efficiency of regeneration is about the same as that of motoring.

Alternating-current series motors have been used with regenerative braking to a limited extent and various schemes are proposed for excitation. The taps on the transformer enables the speed to be controlled all the way from maximum to a standstill and in this respect it is superior to all others. Some of the schemes for excitation are very simple, but usually have the disadvantage of either limited braking power or low power factor, or both. To get the most out of regeneration will require excitation from a phase converter or one of the main motors. With that the locomotive can exert a high braking effort and will have a good power factor.

The electric locomotive is so flexible and capable of so many things that it is likely to be overloaded with all kinds of devices that are not at all essential to its operation. These add very greatly to the apparent complication, but after all do not materially affect the reliability. The trend of the times is towards simplification—the reduction of the locomotive to its lowest terms consistent with good operation. This is undoubtedly the way to get the lowest first cost and maintenance charges.

Regenerative braking should be applied on locomotives which are to be operated over heavy grades, but for level or light grade sections the advantage will hardly be worth the complication.

In conclusion, it may be said that the electric locomotive is so flexible that it can be designed to meet practically any reasonable operating conditions, while its unlimited capacity, its great mileage possibilities, its reliability, its low cost for power, and low cost of maintenance, all make it especially attractive to the railway operator.

California's Lofty Mountains. (*U. S. Geological Survey Press Bulletin No. 477*).—At least sixty mountains in California rise more than 13,000 feet above sea level, but they stand amid a wealth of mountain scenery so rich and varied that they are not considered sufficiently noteworthy to be named, according to the Geological Survey. Yet if any one of these unnamed mountain peaks were in the eastern part of the United States it would be visited annually by millions of people. But California has seventy additional mountain peaks more than 13,000 feet high that have been named, or 130 in all, as well as a dozen that rise above 14,000 feet.

SOME MECHANICAL CHARACTERISTICS OF HIGH-SPEED, HIGH-POWER LOCOMOTIVES.*

BY

A. W. GIBBS.

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In discussing this subject it is proposed to avoid all the questions of relative economy of steam and electric operation, whether the latter be by locomotives or by multiple unit cars, for the reason that these questions have been sufficiently discussed by others who have spoken before the Institute.

With the electric locomotives there are certain questions such as the transmission of power from the motor to the driving wheels and the behavior of the complete locomotive considered as a vehicle, particularly with reference to its effects on track structure, which have not received adequate attention. These problems may best be studied with reference to approved types of steam locomotives and my remarks to-night will principally deal with the results of a comparative trial of steam and electric locomotives which was made in 1907 to secure information along this line in connection with the design of electric locomotives for the Pennsylvania Terminal in New York City. It should be understood that at that time but a limited number of types of electric locomotives were available for comparison.

It is my belief that the greatest difficulties, other than financial, of the electric locomotive are mechanical rather than electrical. None of the mechanical arrangements to be described are ideal by any means, and we must not mistake the absence of heavy repairs in the early years of an installation as truly representative of the expenses which will be met later on.

At first blush it would seem that nothing could be more ideal than the connection of a revolving armature and a revolving driving axle, there being no counter-balance disturbances as in the case of driving by reciprocating parts. As a matter of fact, it is not at all simple, for the reason that the driven axle not only revolves but is displaced bodily as well as angularly in the vertical plane.

* Presented at a meeting of the Mechanical and Engineering Section held Thursday, April 14, 1921.

Moreover, these displacements of axles and wheels, which are not spring supported, occur suddenly, due to irregularities in the track, hence it is desirable to reduce the unsprung weight to a minimum.

The difficulties from these various disturbances are encountered principally at the higher speeds and are those with which we shall mainly deal.

The different methods of communicating motion from the motor to the driving axle may be considered under the following designations:

A. The simplest method from the mechanical standpoint is that in which the armature is carried directly on the driving axle, the axle boxes sliding in vertical pedestals and the face of the field coils being parallel vertically on each side of the armature. In this construction the whole of the field coils can be rigidly secured to the frame and above the supporting springs. This arrangement permits the easy removal of the driving axles and wheels with the least disturbance of other parts. The disadvantages are the increase in the unsprung weight on the axle and the low centre of gravity of the entire motor. So far this drive has been confined to D. C. operation.

B. Next in simplicity is the geared drive, with the gear on the driving axle engaging a pinion on the motor, one end of the motor frame being carried in bearings on the axle, the other by proper nosing on the truck frame. The disadvantages of this arrangement are the low centre of gravity of the motor as a whole, the considerable unsprung weight and the gear wear, principally that of the pinion. Usually the motors are in pairs between pairs of axles, and in consequence the gyratory disturbance is less than where the motor centre coincides with that of the axle. This general type of drive, which is in common use in street car operation, is, undoubtedly, the one having the widest application and operates with both alternating and direct current.

C. The quill arrangement in which the whole motor is concentric with the axle in its normal position, but is not directly connected, the axial opening of the armature being larger than the diameter of the axle. The physical connection between quill and axle is by springs interposed between pockets in the periphery of the driving wheel centre and the arms of a revolving spider connected to the armature. These springs not only transmit the

driving torque, but also compensate for the axial disturbance of the driving axle. In some installations the motor frame as a whole is spring-supported, so as to assist in assuming a position concentric with the axle. This arrangement has been used both on cars and locomotives, including one of the cars used in the historic Berlin-Zossen high-speed trials of 1901 and 1902. The objections are the low centre of gravity of the motor, the distance between the motors measured from the centre of the truck, the fact that the motor can be removed from the axle only by drawing one of the wheels, and that any lack of concentricity between the quill and the driving axle puts a continued and varying inertia stress on the torque springs. In place of the tangential helical springs other arrangements of springs have been used, as for instance in the Zossen cars, where the springs consisted of radial quarter elliptical springs back to back, engaging pockets in the driving wheels.

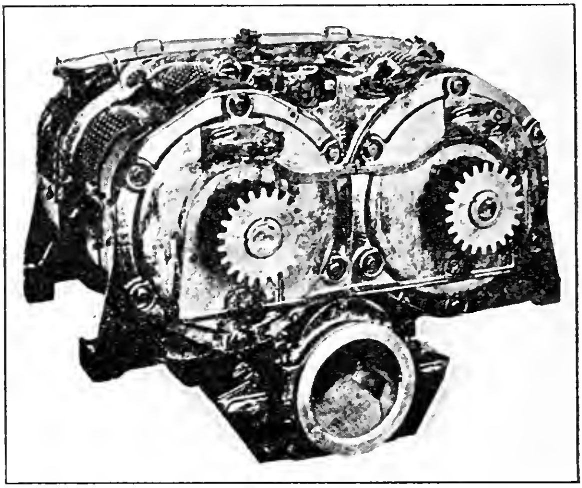
Both arrangements "A" and "C" have the further disadvantage that the ratio of the speed of the motor to that of axle is unity, thus involving higher motor weights than when this ratio is greater.

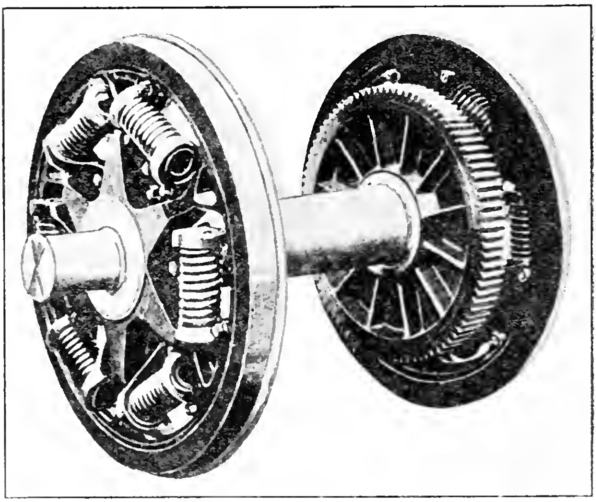
D. A modification of the quill arrangement is where the quill is driven by one or more motors through spur and pinion arrangement (Fig. 1). The advantage of this is that the motor parts are much more accessible than in the concentric type, and that the speed ratio of motor armature to driving axle may vary through a fairly wide range, and that where two motors drive the same quill the tooth load is that of a single motor. The disadvantage is the increased axle distance due to the width over two motors.

E. This group comprises the various drives by coupling rods in a somewhat similar manner to that of steam locomotives, with the exception that one revolving element is a jack-shaft driven by one or more motors and coupled by crank pins and rods to the crank pins of driving axles. The jack-shaft when placed in the horizontal plane of the driving axles maintains a fixed position relative to the driving motor or motors. The relation between them may be a second set of rods coupling the jack-shaft cranks to a similar pair on the motor; or the jack-shaft may be driven through spur or herring-bone gears cut on the periphery of the disk engaging pinions of one or more motors. These rod connections have been used more largely in Europe

than here. The jack-shaft and rod combination is an exceedingly rigid one and the wheel arrangement forms a more rigid

FIG. 1.





Quill Drive with Geared Motors.

connection than in the case of steam driving through pistons. The advantages are that the removal of driving wheels does not involve electric complications, and that all driving wheels in the

group act together, so that the full adhesion of the group is secured, and it is probable that a higher total adhesion will be available from groups than from single units where the slipping of one unit reduces the total adhesion. The disadvantages are mechanical complication involving exact quartering of all wheels and jack-shafts, the necessity of equal diameter of all driving wheels, and the heating of pins and maintenance of rod bushings. Contrary to expectation the maintenance of jack-shafts involves no great difficuity.

In no type of electric locomotive drives are there counter-balance disturbances due to counterweights, as only rotating masses are in motion.

STARTING POWER OF LOCOMOTIVES.

As governed by adhesion the motor-driven axle in starting has a relatively high adhesion because of the uniform torque of the motor. It is a well-recognized fact that static weighings of locomotives show considerable discrepancies on individual axles. How this discrepancy varies in moving locomotives is not known.

Assuming that the motor torque is greater than adhesion resistance, we have, where axles are individually driven, the adhesion of the axle with the lightest loading governing the adhesion of the group. Where, on the other hand, there is a rod connection between the various axles, we utilize the full adhesion of the group. The presence of the coupling rods does not preclude the application of power to any axle or number of axles, though the usual practice has been to apply all the power to one or more jack-shafts and from them to a group of axles. This utilization of the full adhesion in starting is a matter of importance in any type of locomotive, as usually they will pull heavier trains than they will start.

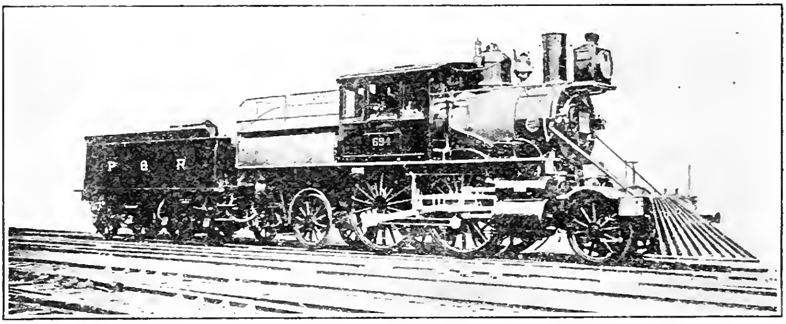
STABILITY OF LOCOMOTIVES.

In the earlier days of steam locomotives the aim was to keep the vertical centre of gravity low with the idea that this was conducive to stability. Not until the Reading Railroad in its introduction of the wide firebox type of locomotive was forced to elevate the boiler so that the firebox would clear the driving wheels, was it recognized that this change had materially improved the steadiness of the locomotive as a vehicle. The reason,

of course, was that the centre of gravity of the parts above the springs acting as an inverted pendulum failed to respond to the many small disturbances which would otherwise have produced side shocks. Since that time designers have not hesitated to raise the centre of gravity of the parts above the springs, and the present limits are chiefly those of overhead clearance.

One other steam locomotive lesson that seems to have been forgotten was that with a short symmetrical wheel arrangement with heavy overhanging weights distributed longitudinally of the whole machine, excessive lateral oscillations were set up which endangered the track and locomotive. Figs. 2 and 3 show loco-

FIG. 2.



Columbian Type (2-4-2) Locomotive.

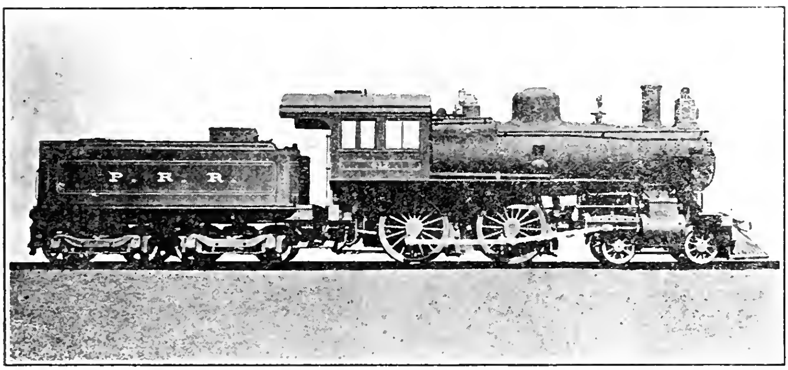
motives of the Columbian or 2-4-2 type and the American or 4-4-0 type. Here are two types of almost the same total wheel-base with nearly the same height of boiler above rail. The weight of the 4-4-0 type was but 7 per cent. greater than that of the 2-4-2 type. The 2-4-2 type was so unstable that it was soon condemned. The 4-4-0 type is notably a steady-running one and its performance will be graphically shown later. The reason for the difference in performance is probably that the wheel arrangement of the 2-4-2 was symmetrical, while that of the other was not.

In the Berlin-Zossen trials the electric cars were carried on two six-wheel trucks the outside axles of each truck being motor-driven by the quill drive. In the original construction the wheel-base of each truck was approximately 12 feet 6 inches, and the trucks were spaced about 48 feet 10 inches, the total length of the vehicle being a little over 72 feet. The road was what would

be considered light as to rail and ballast. When speeds above 90 miles per hour were reached the track began to go to pieces and had to be rebuilt. The construction of the rebuilt track, especially the very elaborate lateral bracing, indicates the severe effect of the lateral shocks in the original trials. The trucks were also rebuilt, the wheel-base being lengthened to 16 feet 5 inches. With the rebuilt roadway and car, speeds up to 125 miles per hour were reached with impunity. This is, so far as known, the highest speed attained by any wheeled vehicle.

The single-unit car does not meet the requirements of passenger transportation as we see it in this country, and the develop-

FIG. 3.



American Type (4-4-0) Locomotive.

ment of electric operation has followed two lines, *viz.*, the substitution of electric for steam locomotives for through service and the use of multiple-unit trains for suburban work. With the latter we will not deal.

When it became necessary to design locomotives to operate the New York terminal of the Pennsylvania Railroad two electric locomotives were designed and built.

Both consisted of two four-wheel trucks with motors for each axle. In both cases the trucks were articulated at the centre and carried the necessary draft gear at the ends, thus the pull was transmitted through the frames of the trucks and not through the superstructure.

In one of these locomotives the motor drive was by gear,

the second method referred to. The other was driven by four concentric motors through quills.

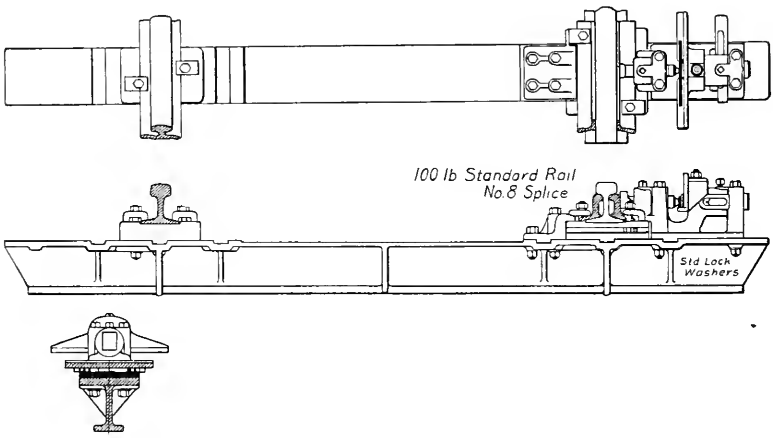
The wheel-base of both were identical, that of the trucks 8 feet 6 inches and the total 26 feet 1 inch.

Both operated by direct-current at 650 volts through third rail.

About the time that they were completed reports of troubles elsewhere made it very desirable that we should ascertain their performance before constructing the large number of locomotives necessary for the operation of the tunnels.

The line of the West Jersey was available for track and current, and it was decided to construct an experimental track with

Fig. 4.



Assembled Recording Tie.

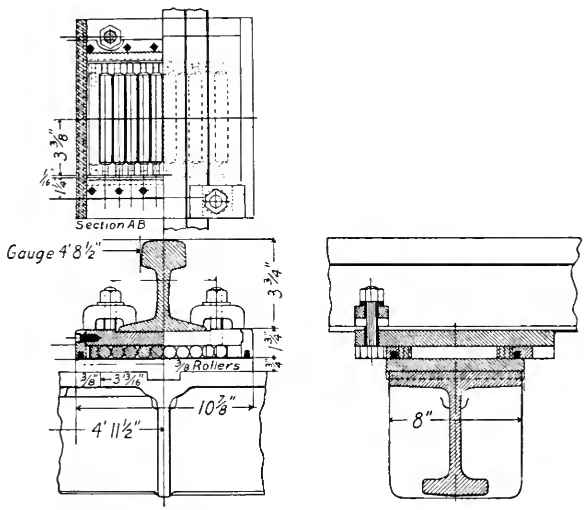
ties which would make some permanent record of the lateral impacts of the locomotives. As it was expected that the bad oscillations would occur on curves, if anywhere, only one end of the tie was arranged to register.

Figs. 4 and 5 show these ties, the end at the outer rail being so constructed that the rail was free laterally, resting on rollers, resisted against outward movement by a bracket carrying a strip of boiler plate, movable longitudinally at will. Against this strip rested a one-inch steel ball which in turn bedded in a plunger bearing against the outside face of rail. (Fig. 6 shows the test track arranged to record at each end, as referred to later; Fig. 7 shows one of the impression plates carrying the record of 30 runs.)

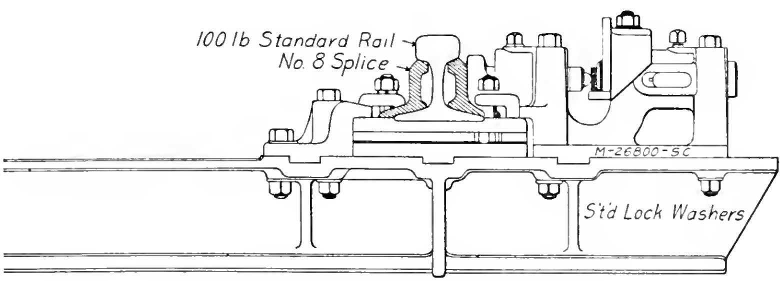
The record obtained with this device was a species of glorified

Brinell tests, the depth of the impressions of the one-inch ball in the boiler plate being taken as a measure of the impact. After each run the plates were slipped longitudinally and adjusted to touch the ball, each single plate taking the record of 30 or more runs. It is to be clearly understood that this method carries

FIG. 5.



Recording End of Tie.

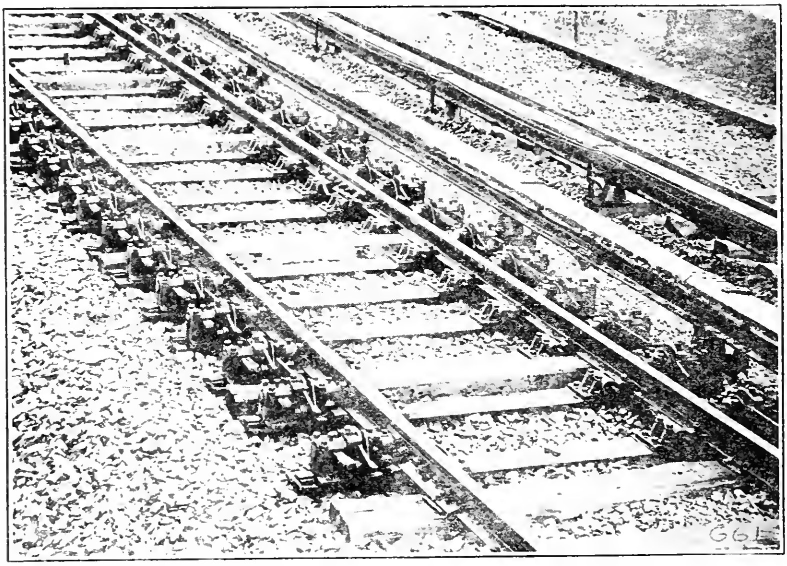


Recording Tie Showing Ball and Boiler Plate Strip.

with it some decided limitations which must not be overlooked. Each run, whether with one or more vehicles, made a single impression on each plate. While it was assumed that the indentation was that of the heaviest impact, it is possible that two or more impacts occurred on a single point with some cumulative effect. In some of the runs it is believed that this was the case.

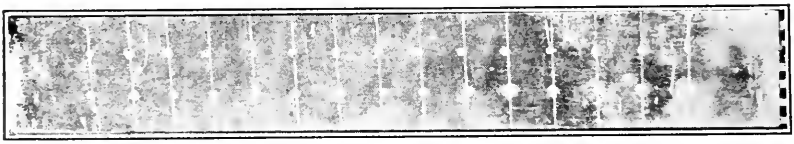
There was also some question as to the interpretation of the impressions. They were calibrated by static loading in the testing machine and also dynamically by falling weight. The calibration curves showing the results of both of these methods are shown in Figs. 8 and 9.

Fig. 6.



Recording track as subsequently modified to register at each end of each tie.

Fig. 7.

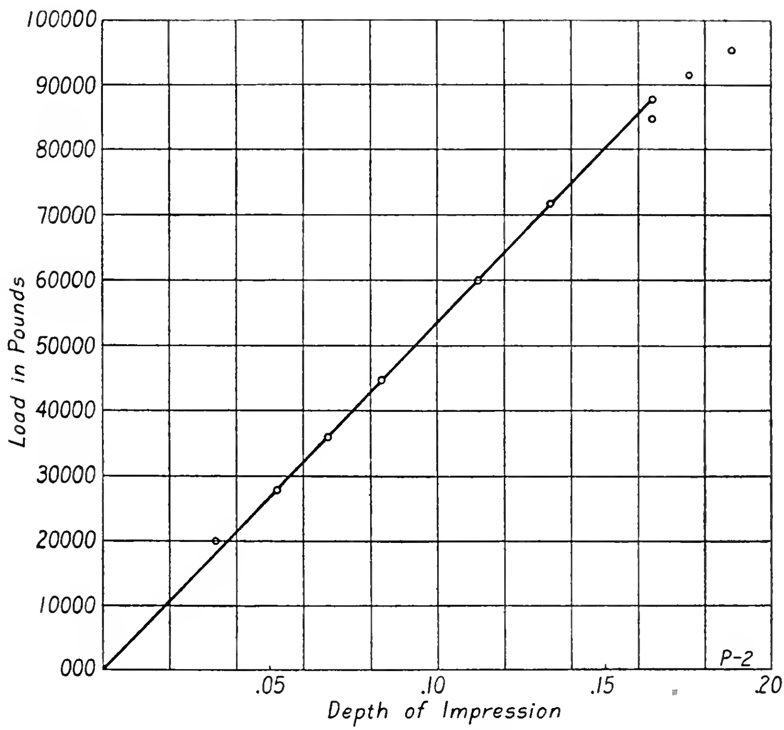


Strip showing impressions.

The recording ties, 80 in number, extending over five rail-lengths, or a total distance of 165 feet, were laid on a one-degree curve in the southbound track, near Franklinville, New Jersey, in 1907. There were 16 of the recording ties to each rail-length and at every splice on both rails the two ties at the splice were so located that the joint between the rails came between the

ties, which at this point were 20 inches apart. The other 14 ties were spaced as uniformly as possible, taking into consideration the necessities for spacing at the rail joints. Tie No. 1 was placed about 28 feet south of the point of curve. The superelevation of the outer rail of curve was 3 inches, and the elevation

FIG. 8.



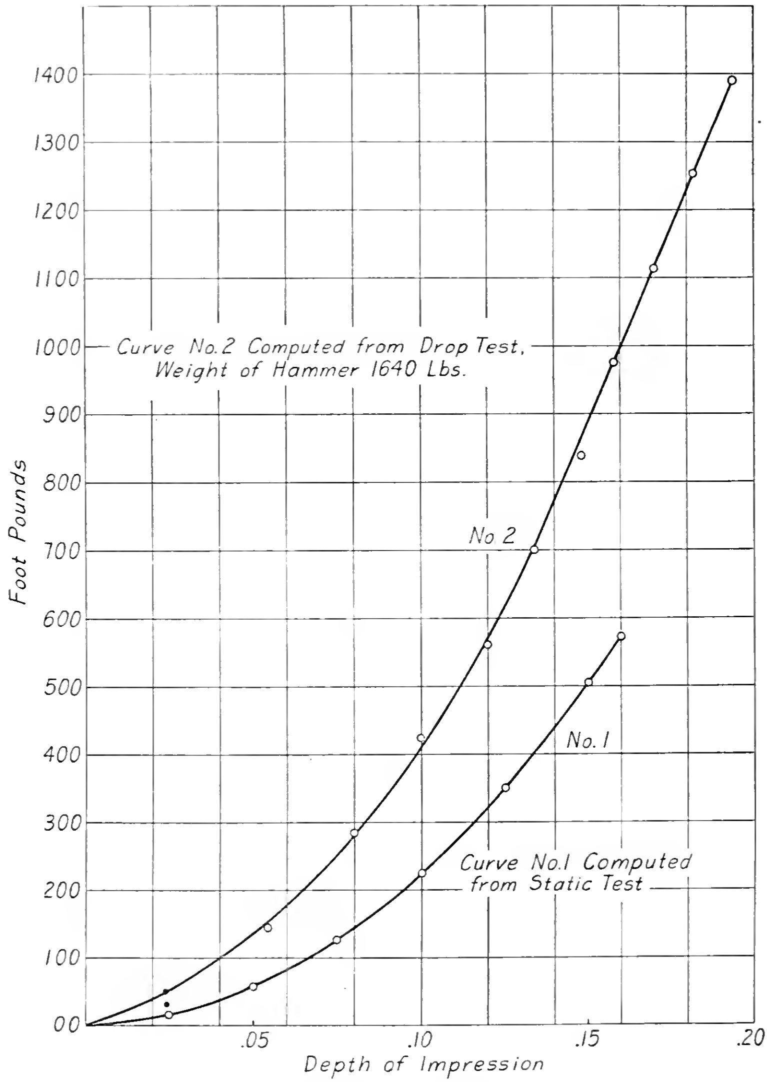
Static calibration of impressions.

of the rail began at a point about 250 feet north of the point of curvature.

Tie plates were used on wooden ties immediately south of the test track for one-quarter of the distance around the curve. The ballast used at the curve was gravel and cinder. The rails were P. R. R. section, 100 pounds to the yard, in good condition. It was specified in arranging the experimental track that it should be lined up in about the best average condition of track used on this piece of road.

The tangent track approaching the curve from the north consisted of 100-pound rails supported by wooden ties, single

Fig. 9.



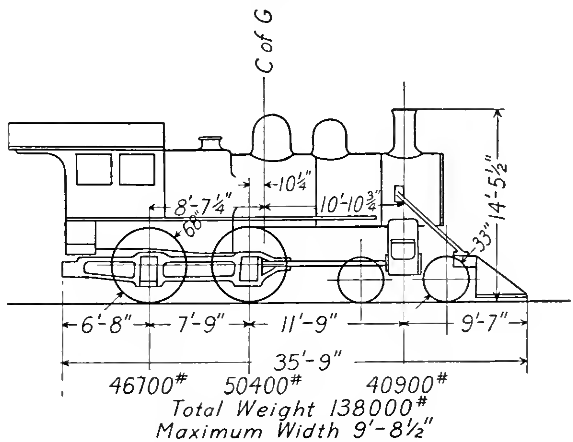
Calibration of impact test.

spiked. The substructure was of broken stone ballast with the exception of about 1500 feet north of the test track, in the

vicinity of Clayton, where most of the runs were started and where cinder and gravel ballast were used.

After the completion of the runs on the curve, the recording ties were removed to the tangent north of Franklinville station, where the trials were completed. At this location the track consisted of 100-pound rail with broken stone ballast. The speed record was obtained by means of a series of trips, operated by the locomotive passing over them, which broke and made the circuit going to the chronograph. These trips were located such dis-

FIG. 10.



American Type (4-4-0) Locomotive.

tance apart that at a speed of 100 miles per hour the time between trips would be one second. Four trips were used for the tests on the curve and seven for those on the tangent, the idea being that failure of one or two trips would not vitiate the record of the run.

Other apparatus used in the tests consisted of speed recorders on the locomotive, which were used only to obtain approximate speeds; and in some of the runs, there was placed on the locomotive a seismograph having three pendulums, giving vibrations in vertical, transverse and longitudinal directions.

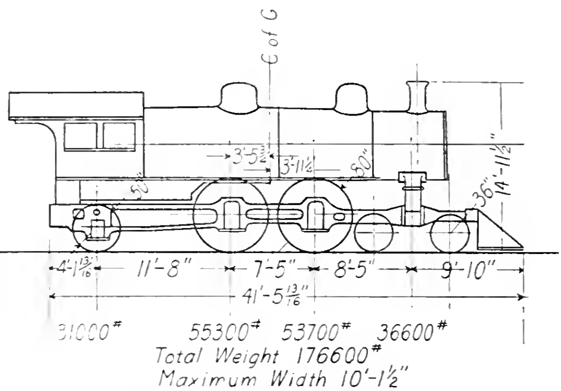
For the equipment, there was a choice of a wide variety of steam locomotives, and four electric locomotives were available.

The steam passenger locomotives elected were, one of the

4-4-0 or American type (Fig. 10), the other of the 4-4-2 or Atlantic type (Fig. 11).

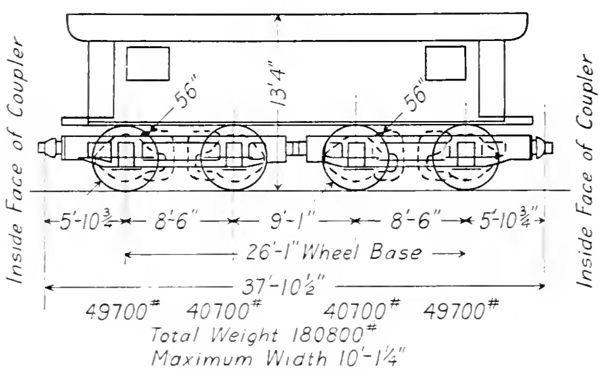
The electric locomotives were Nos. 10,001 (Fig. 12) and 10,002 (Fig. 13) already described; No. 10,003, or American type, that is, with two pair of driving wheels and a four-wheel

FIG. 11.



Atlantic Type (4-4-2) Locomotive.

FIG. 12.



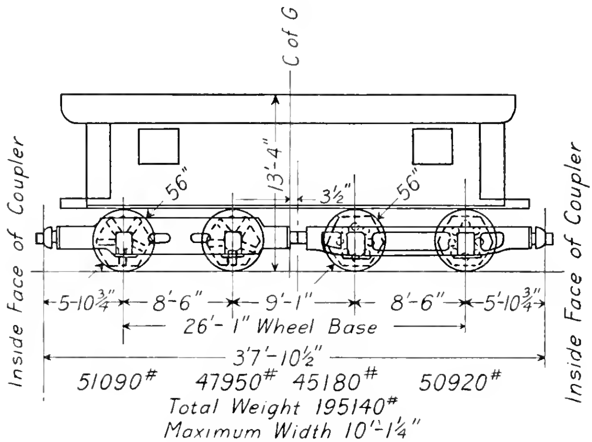
Electric Locomotive, No. 10,001, Geared Drive Type B.

truck (Fig. 14); and No. 028, a brand-new locomotive belonging to the New York, New Haven and Hartford Railroad, which consisted of two four-wheel trucks pivotally connected to the body which carried the draft attachments (Fig. 15).

The drives of Nos. 10,003 and 028 were very similar, consisting of a quill drive (type C).

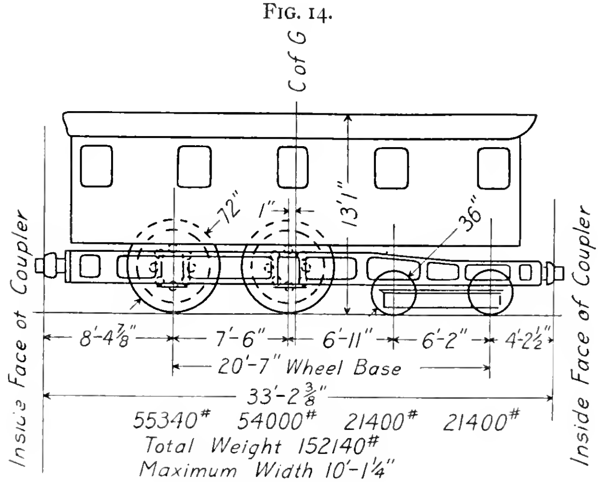
Locomotive No. 10,003 was arranged for A. C. operation, which necessitated provision for D. C. control operation, which

FIG. 13.



Electric Locomotive, No. 10,002, Quill Drive Type C.

FIG. 14.



Electric Locomotive, No. 10,003, Quill Drive Type C.

was placed in a separate car that always accompanied the locomotive.

No. 028 was arranged with double control, A. C.-D. C., so as to facilitate its operation into Grand Central Terminal, New York.

Considered from various standpoints these locomotives ranked as follows:

As regards wheel-base:

	Total Wheel-base	Distance center to center of trucks.
Electric Loco. No. 10,003	20′ 7″	17′ 6″
Electric Loco. No. 028	22′ 6″	14′ 6″
Steam, American Type (4-4-0)	22′ 9½″	19′ 6″
Electric, No. 10,001 and No. 10,002	26′ 1″	17′ 7″
Steam, Atlantic Type (4-4-2)	30′ 9½″	

As regards center of gravity:

	Vertically	Longitudinally
Electric Loco. No. 10,002	42½″ above rail	3½″ from center
Electric Loco. No. 10,001	45¼″	Centrally
Electric Loco. No. 028	55″	Centrally
Electric Loco. No. 10,003	55″	1″ ahead of front drivers
Steam, American Type, (4-4-0)	63″	10¼″ ahead of front drivers
Steam, Atlantic Type, (4-4-2)	73″	41¼″ ahead of rear drivers

Thus, if length of wheel-base is to govern, the Atlantic-type steam locomotive is the best, and the American-type electric, No. 10,003, should be the worst.

If height of centre of gravity is to be the deciding factor, the Atlantic steam locomotive is still the best, and the articulated quill-drive electric No. 10,002 the worst.

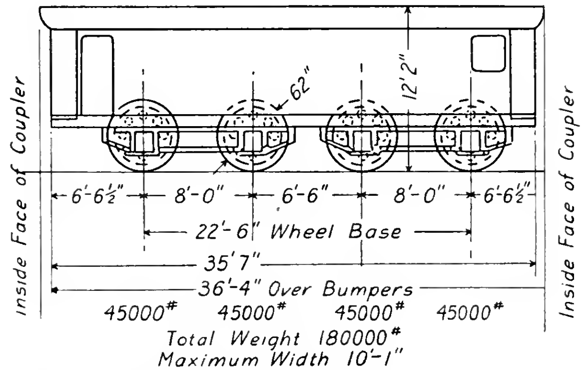
As the object of the trials was to determine stability at express speeds, very few of the runs were made at lower ones, but it is fair to say that with any type of locomotive, steam or electric, not much disturbance should be expected at low speed, consequently progressive speeds were selected up to the maximum speed capacities of the various locomotives.

The runs with the steam locomotives went off very smoothly. Typical records are shown at different speeds for each type (Figs. 16 and 17). The maximum speed for the 4-4-0 type was 83 miles per hour, and for the 4-4-2 type, 95 miles per hour. It is not to be understood that these are practical operating speeds.

When the electric locomotives were run the story was very different, as will be seen from the diagrams (Fig. 18). The record for the geared locomotive, No. 10,001 (type B), shows

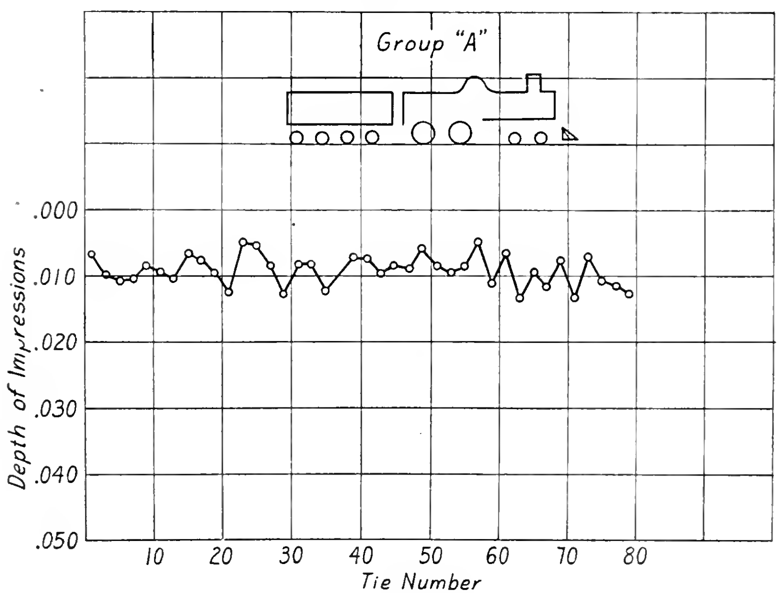
severe oscillation with either end leading, there being three rather pronounced peaks at about the same space interval.

FIG. 15.



Electric Locomotive, No. 028, Quill Drive, Type C. Pivotted Truck.

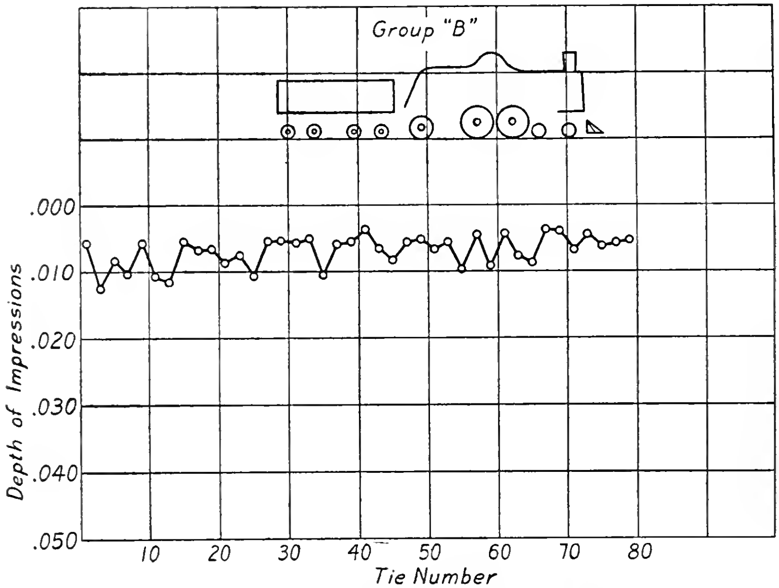
FIG. 16.



Steam Locomotive, American Type (4-4-0), Speed 83.5 M.P.H.on Curve.

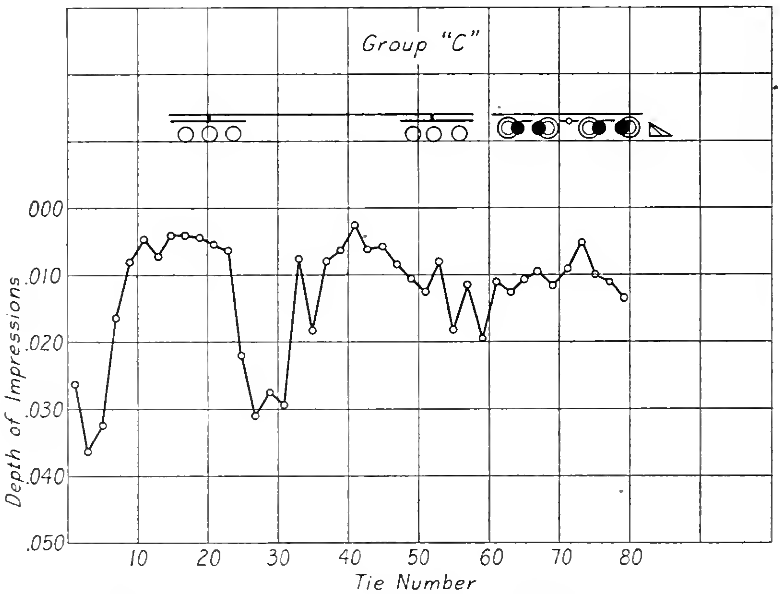
The maximum depth of impressions would indicate a lateral severity about double that with steam locomotives. It is probable that had the ties been arranged to record impressions at each end,

FIG. 17.



Steam Locomotive, Atlantic Type (4-4-2), Speed 95.7 M.P.H., on Curve.

FIG. 18.

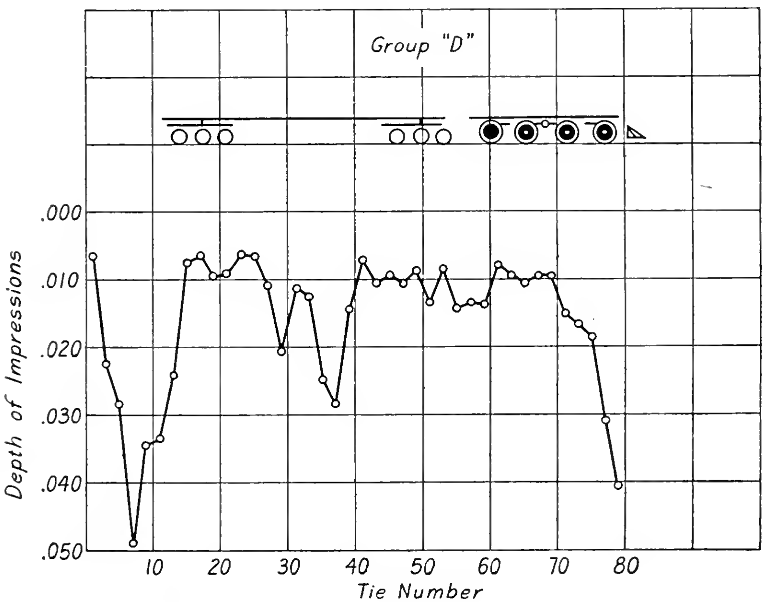


Electric Geared Locomotive, No. 10,001, Speed 71.5 M.P.H., on Curve.

intermediate impacts would have been shown on the opposite rail.

With No. 10,002, articulated quill drive, the records both of depth of impressions and of the seismograph were decidedly the worst of all the locomotives under trial (Fig. 19). While runs were being made with this locomotive the tangent approach track began to spread, with results shown in Fig. 20. The greatest spread was 7/8-inch, which caused kinking of the rail and bending of the spikes as shown in Fig. 21. The same thing hap-

FIG. 19.



Electric Locomotive, No. 10,002, Speed 68.3 M.P.H., on Curve.

pened in varying degree where runs were made with different locomotives coupled together, but only when locomotive No. 10,002 happened to be one of the combination.

With the non-articulated locomotive, No. 028, the readings both of the impressions (Fig. 22) and of the seismograph showed a very much better performance, and so far as this set of tests went, the locomotive could not be considered bad. It was, however, tried only on the tangent track after the completion of the tests on the curve. The subsequent history of this type of locomotive in service showed that as wear accumulated the lateral

oscillation became serious, so much so that the locomotives were changed by the addition of a third carrying axle to each truck, thus forming a non-symmetrical arrangement and at the same

FIG. 20.

Tangent Track Kinked by Electric Locomotive No. 10,002.

time providing a longer wheel-base. In the light of subsequent tests, it is probable that the smoothness of the diagram for this locomotive was largely due to the absence of end play of the axles in their boxes.

The last of the electric locomotives, No. 10,003, was in fact an eight-wheel American-type locomotive, and the records on both curve and tangent at once put it in the class of the best steam locomotives (Fig. 23). As originally constructed the leading truck had free lateral motion, and an extensive set of runs in both directions showed that while the free swing was an advantage when the truck led, it was a disadvantage when it trailed, and that the best compromise was with truck rigid laterally.

FIG. 21.

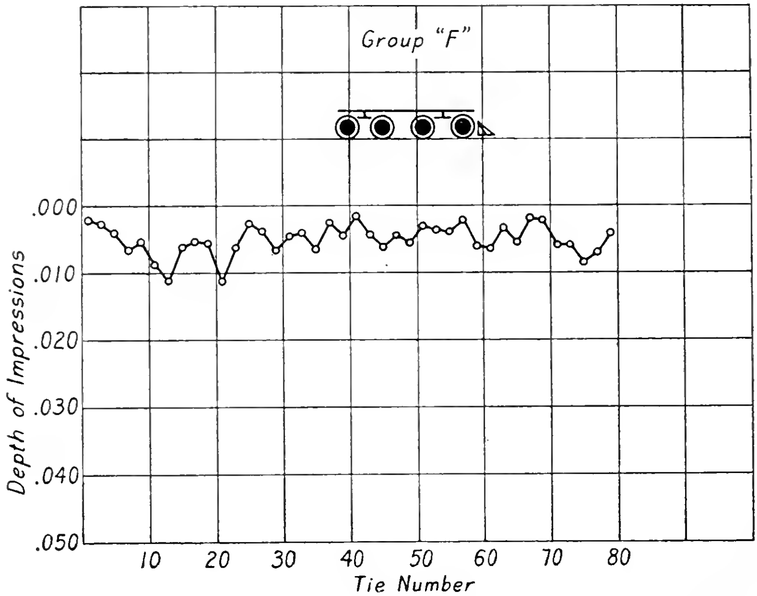
Spikes bent as result of lateral impact on tangent tracks.

These Franklinville tests concluded with runs of different combinations of locomotives coupled together. Apparently when the locomotives were coupled, the number of impressions was increased, but there was no material increase in the depth.

It appeared that in all combinations, including the articulated quill-drive locomotive No. 10,002, the riding of the companion locomotive was worse than when operated by itself (Fig. 24).

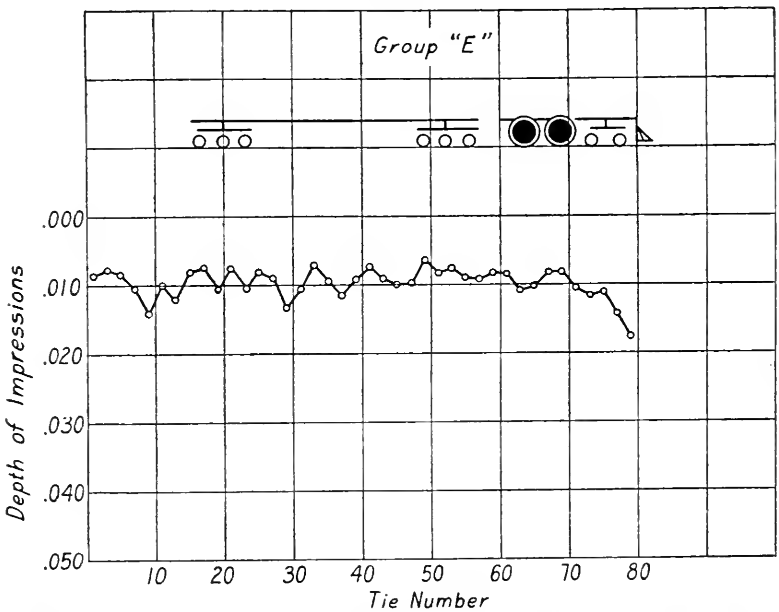
The influence of the approach track had a very marked effect on the results. It was evident that for best results the recording track should have been very much longer to record the resonant

Fig. 22.



Record of Impressions with Electric Locomotive No. 028., on Tangent, Speed 88.3 M.P.H.

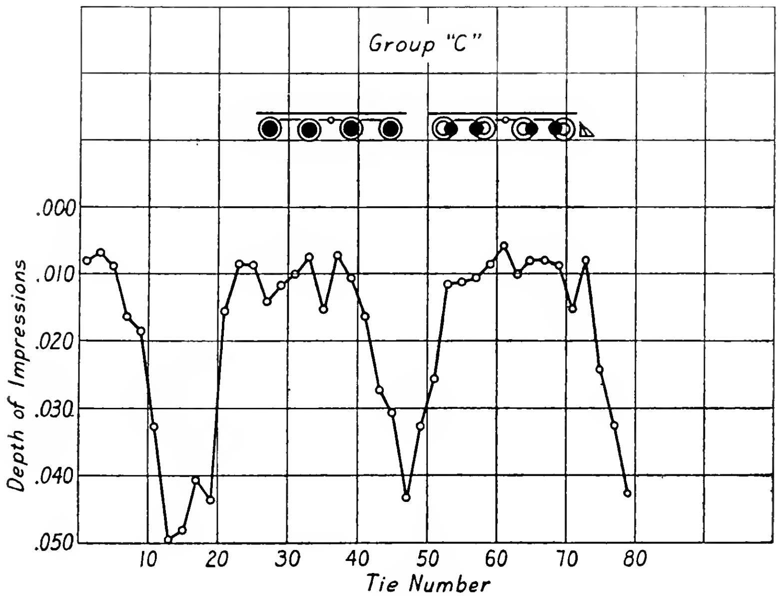
Fig. 23.



Record of Impressions with Electric Locomotive No. 10,003, (4-4-0), Speed 82.6 M.P.H. on Curve.

type of oscillations from their origin through their development to the final dampening. It was also evident that the ties should have been arranged to record on each end.

FIG. 24.



Record of Impressions with Electric Locomotives Nos. 10,001 and 10,002., coupled speed 71.6 M.P.H., on curve.

The severity of the impacts from the impressions measured statically is indicated by the following notes on rail pressures at speeds above 60 miles per hour:

Group A—Steam Locomotive.

No. 6034, Type D-16b (4-4-0).

Maximum readings of 6 runs, speeds between 60.07 and 83.2 M.P.H.
At 60.07 M.P.H.—Impression .0135″—Pressure 7250 lbs.
At 80.0 M.P.H.—Impression .0141″—Pressure 7580 lbs.
Average—74.3 M.P.H.—Impression .0123″—Pressure 6610 lbs.

Group B—Steam Locomotive.

No. 6020, Type E-2, (4-4-2).

Maximum readings of 7 runs, speeds between 59.6 and 95.7 M.P.H.
At 71.2 M.P.H.—Impression .0129″—Pressure 6930 lbs.
At 80.8 M.P.H.—Impression .0159″—Pressure 6550 lbs.
Average—74.4 M.P.H.—Impression .0123″—Pressure 6500 lbs.

Group C—Electric Locomotive No. 10,001.

Forward, No. 2 end ahead.

Maximum readings of 6 runs, speeds between 61.1 and 71.3 M.P.H.

At 71.3 M.P.H.—Impression .0272″—Pressure 14620 lbs.
At 67.9 M.P.H.—Impression .0193″—Pressure 10370 lbs.
Average—64.5 M.P.H.—Impression .0165″—Pressure 8870 lbs.
Reversed, No. 1 end ahead.
Maximum readings of 4 runs, speeds between 60.9 and 70.1 M.P.H.
At 62 and 70.1 M.P.H.—Impression .0289″—Pressure 15530 lbs.
At 69.7 M.P.H.—Impression .0298″—Pressure 16000 lbs.
Average—65.7 M.P.H.—Impression .0267″—Pressure 14350 lbs.

Group D—Electric Locomotive No. 10,002.

Maximum readings of 4 runs, speeds between 60.8 and 60.8 and 68.1 M.P.H.
At 62.8 M.P.H.—Impression .039″—Pressure 20960 lbs.
At 66.0 M.P.H.—Impression .0311″—Pressure 16720 lbs.
Average—64.4 M.P.H.—Impression .0291″—Pressure 15640 lbs.

Group E—Electric Locomotive No. 10,003 (4-4-0).

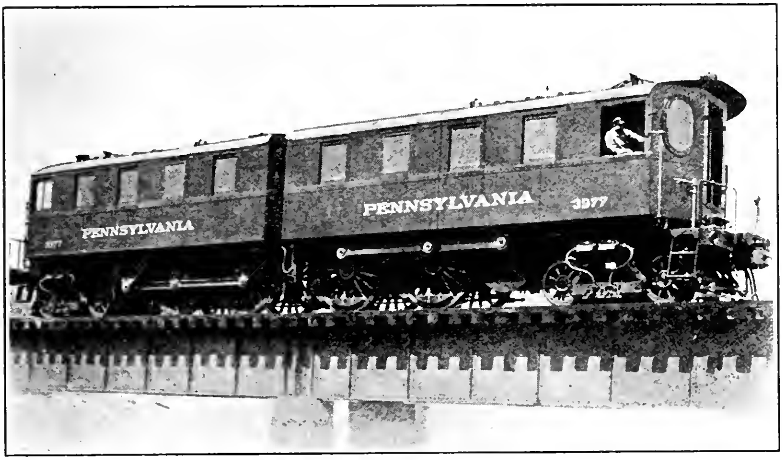
Forward, bolster free.
Maximum readings of 8 runs, speeds between 60.8 and 88.3 M.P.H.
At 63.3 M.P.H.—Impression .0123″—Pressure 6610 lbs.
At 72.38 M.P.H.—Impression .0125″—Pressure 6720 lbs.
Average—74.1 M.P.H.—Impression .0113″—Pressure 6070 lbs.
Forward, bolster blocked.
Maximum readings of 6 runs, speeds between 60.0 and 83.9 M.P.H.
At 75.1 M.P.H.—Impression .0179″—Pressure 9620 lbs.
At 83.9 M.P.H.—Impression .0193″—Pressure 10370 lbs.
Average—73.5 M.P.H.—Impression .0149″—Pressure 8010 lbs.
Reversed, bolster blocked.
Maximum readings of 5 runs, speeds between 65.5 and 84.0 M.P.H.
At 65.5 and 70 M.P.H.—Impression .0115″—Pressure 6180 lbs.
At 68.2 M.P.H.—Impression .0117″—Pressure 6290 lbs.
Average—74.04 M.P.H.—Impression .0106″—Pressure 5700 lbs.
Reversed, bolster free.
Maximum readings of 5 runs, speeds between 60.4 and 77.5 M.P.H.
At 68.9 M.P.H.—Impression .0289″—Pressure 15530 lbs.
At 70.2 M.P.H.—Impression .0281″—Pressure 15100 lbs.
Average—68.9 M.P.H.—Impression .0236″—Pressure 12700 lbs.

Group F—New Haven Electric Locomotive No. 028.

Maximum readings of 9 runs, speeds between 60 and 88.3 M.P.H.
At 70.7 and 72.6 M.P.H.—Impression .0197″—Pressure 10370 lbs.
At 70.8 M.P.H.—Impression .0186″—Pressure 10000 lbs.
Average—71.7 M.P.H.—Impression .0149″—Pressure 9000 lbs.

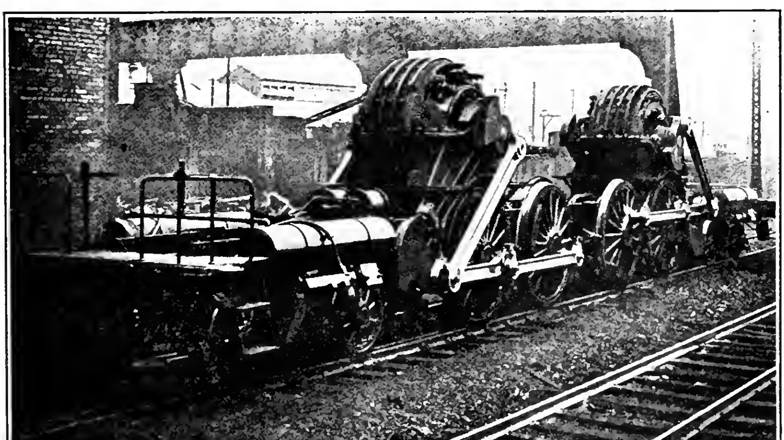
The outstanding fact seemed to be the superior performance of the locomotive with the non-symmetrical wheel arrangement over that with the double four-wheel motor-driven trucks. The articulated truck arrangement was undoubtedly the worst of the combinations, but how much of this was due to the low centre of

FIG. 25.



Type of Electric Locomotive Finally Adopted.

FIG. 26.



Chassis of Electric Locomotive Finally Adopted.

gravity and how much to the articulation setting up a snaking motion was not definitely established.

It is to be noted that one of the double truck motor-driven locomotives and one with two driven axles and leading truck had the same height of centre of gravity, and the latter arrangement was decidedly the better. The comparison is the more interesting because in both of these locomotives the same quill-drive type is used.

The action as the result of the tests was the condemnation of both types of articulated electric locomotives and the preparation of an entirely new design.

The new design consisted of two eight-wheel American-type locomotives coupled back to back, each driven by one motor in the cab and coupled by cranks and rods to a jack-shaft placed in the horizontal axis of the driving wheels, and coupled to them by rods, as in this case of steam locomotives (Figs. 25 and 26). In this design were embodied not only the non-symmetrical wheel spacing of each semi-unit, but also the elevation of the centre of gravity of the spring-borne portion. This design was completed and locomotives built and tested in time to start the operation of the New York Terminal in 1910, and the locomotives have satisfactorily performed that service ever since.

It is not claimed that the question of stability is fully understood. The selection of available wheel arrangements was very limited, but prompt decision was imperative. It is felt that this investigation should be considered as only a starting point for a much more extensive one, which should determine the most desirable arrangements of wheels, of height of centre of gravity, and method of motor drive.

So far as this particular investigation was concerned, the question of electric system was not involved, but, of course, a full discussion of the characteristics of steam and electric locomotives cannot ignore such questions.

Since this set of tests with single-ended ties, other series have been made in which the ties were arranged to record at each end. More ties were used so as to lengthen the test track. As for the equipment, the test included different methods of coupling the semi-units of electric locomotives; also studying the effect of depressions purposely placed in the approach track, the effect of different amounts of end clearance in the axle boxes, variation

in the amount of counterbalancing in steam locomotives, etc. The whole accumulation of data is too voluminous to be included in one paper. Although considerable practical information of value has resulted from the various trials, there is much work yet to be done before the questions of stability are really understood. It is to be regretted that the selection of electric locomotives did not include greater variations in the wheel-base, the method of articulation and height of centre of gravity, but it is believed that the work already done is a very good starting point for future investigations.

Study of Early Fossils. (*U. S. Geological Survey Press Bulletin No. 477*).—The fossil shells of the early invertebrates, or spineless creatures, are of great importance to geologists, for they indicate the geologic period in which the rock beds containing them were formed—in other words, the age of the rock. Each fossiliferous rock bed contains characteristic forms or groups of forms that determine the period in which it was mud or sand. Former Director Powell, of the United States Geological Survey, once tersely explained to a congressional committee the value of paleontology by saying that it is "the geologist's clock," by which he tells the time in the world's history when any rock bed was formed.

The economic importance of paleontology has been repeatedly shown in this country. In the earlier exploitation of anthracite coal thousands of dollars were fruitlessly expended in New York in search of coal beds, until the New York geologists showed that the beds in that State could contain no coal. The fossils in the New York rocks exploited are of Devonian age, whereas the fossils of the Pennsylvania anthracite coal beds belong to the Carboniferous, a much later period. This discovery at once stopped a useless expenditure of money.

In times of doubt and perplexity the geologist therefore turns to the paleontologist for light on the age and original order of the rock beds he is studying. The study of the animal and plant remains that are embedded in the rocks has thus become an important part of geologic work, and although the specialists who are engaged in this study are few, their work is of high importance.

High Altitudes in Montana. (*U. S. Geological Survey Press Bulletin No. 477*).—Six named peaks in Montana have elevations exceeding 12,000 feet, and several unnamed peaks rise to greater heights, according to the Survey. All these peaks are in the Beartooth National Forest, in Carbon County, in the south central part of the State. The highest of these is Granite Peak, 12,850 feet; the next highest is Mount Wood, 12,750 feet.

Bacteriologic Separation of Hydrocarbons.—MARTA PETER, in a thesis submitted to the Technical High-school in Karlsruhe, which was published in *Centralblatt f. Bakter., Parisit. u. Infect.*, in 1919, describes in much detail, experiments with bacteria which have the power to appropriate some aliphatic hydrocarbons, in the presence of certain cyclic hydrocarbons, but without affecting the latter. Three forms of bacteria are described termed, respectively, *B. aliphaticum, B. aliphaticum liquifaciens,* and one not definitely named, provisionally "paraffin bacterium." These organisms were obtained from garden earth. Full accounts are given of the methods of isolating and cultivating them, and their morphology. The test analyses were very numerous, and the investigator claims that a practical method for the analysis of petroleum oils has been developed. An interesting point in the paper is the fact that the cyclic hydrocarbons do not have any distinct restraining action on the growth of the bacteria used. H. L.

Detection of Carbon Monoxide.—The detection of this substance in air and other gases, when present in quite small proportion has been a problem of importance and of some difficulty. It is a very poisonous gas, having a special cumulative effect, by which the continued inhalation of very small amounts will ultimately produce serious conditions. C. R. Hoover, of Wesleyan University, gives an account in the *Jour. Ind. Eng. Chem.* (1921, xiii, 770) of the use of a new reagent, Hoolamite, which consists of fuming sulphuric acid and iodine pentoxide, mixed with an inert supporting material. This reagent was the subject of a patent by Messrs. A. B. Lamb and C. R. Hoover, from which presumably the uncouth name is derived. The inert material used is pumice. The reaction is the conversion of the reagent into a green mass, the depth of color being mainly proportional to the concentration of the carbon monoxide in the gas tested. Two portable devices are described by which tests may be made away from the laboratory and an approximate quantitative measurement made. It has been found that one of these devices is sufficiently sensitive to detect in a few seconds carbon monoxide in proportions believed to be harmless to human beings or the larger animals. The use of the instruments is not difficult, and it is hoped that very soon further improvements will be made in the preparation of the reagent and the operation of the apparatus. Carbon monoxide is, however, not the only gas which reacts, but all other gases, so far tested, that simulate it, are absorbed by dry animal charcoal, which does not appreciably absorb carbon monoxide. Some common gases are entirely without action. Hoolamite is a corrosive, deliquescent material, and must be kept in closed vessels. Its activity increases for a few days after preparation, then becomes stationary and remains so for a long while. It is usually kept in small sealed glass tubes. H. L.

ELECTROLYTIC WATER-PROOFING OF TEXTILE FABRICS: THE TATE PROCESS.* †

BY

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PRIOR to the advent of the electrolytic method, the art of water-proofing textile fabrics was confined to two methods: Mechanical processes and chemical processes.

Mechanical processes embrace all methods which involve direct impregnation, filling or coating the fabrics with rubber, waxes and various compounds which achieve the result of rendering them proof against the penetration of both water and air. In view of the fact that the vast majority of the uses for which textile fabrics are designed requires that they possess the quality of ventilation, all of these mechanical processes are correlatively restricted in their application and are employed most largely in association with fabrics intended for specific uses wherein air circulation is a negligible factor; when used in associations where ventilation is an essential factor, notably for wearing apparel such as raincoats, the results are unsatisfactory from the viewpoints of both comfort and hygiene.

Chemical processes embrace all methods whereby a coating of a water-repelling substance is deposited on the surfaces, yarns or fibres of textile fabrics through the media of chemical reactions. These methods are designated as follows: (1) The *aluminium soap process;* (2) the *lanolin process;* (3) the *cuprate of ammonia process.* Since the electrolytic method of water-proofing described in this paper involves the impregnation of fibres with aluminium compounds, the first of these chemical processes will be described briefly.

In the aluminium soap process, which is one of the most largely employed where ventilation is an essential factor, the fabric is first saturated with a relatively heavy solution of soap and then passed

* Communicated by the Author.

† This paper embodies the results of an investigation of the Tate process of electrolytically water-proofing textile fabrics by the Committee on Science and the Arts of The Franklin Institute.

through a solution of alum, aluminium sulphate or aluminium acetate. Owing to the reaction which takes place between the soap and the aluminium salt, an aluminium soap (aluminium oleate or aluminium palmitate) is deposited on the yarns or fibres of the fabric in the form of a veneer or coating. While this veneer is fresh it is highly elastic, adhesive and water-repelling, but unfortunately these conditions subsist only for a short time. When the fabric is exposed to the drying influence of the atmosphere, deterioration is rapid, and in a few weeks the qualities of elasticity and adhesiveness disappear and the aluminium soap becomes friable, breaking away from its anchorage and thus restoring the fabric to its original absorptive condition. Furthermore, while the aluminium soap is insoluble in water, it is dissolved by gasoline, benzine and various other solvents employed in the process known as dry-cleaning. Garments water-proofed by this process cannot be dry-cleaned without partially or wholly destroying their water-repelling qualities.

The first mention of an attempt to apply electricity to the art of water-proofing textile fabrics is contained in U. S. Patent No. 558,717, issued to H. L. Brevoort in 1896. In Brevoort's process the fabric, previously moistened with water, is placed "between and in contact with an anode of an oxidizable metal and a cathode of conducting material covered with an absorbent fabric," and, owing to the physical contact between the surface of the anode and the fabric, the oxide formed at the positive electrode is deposited "on or in the fabric." Since, however, Brevoort did not provide any apparatus for applying his process on other than an experimental scale, his results are only of interest as experiments. Besides, fabrics treated by this method are but partially water-proof.

Four years later a patent [1] representing an attempt to provide a mechanism to apply the Brevoort water-proofing process to textile fabrics on an industrially operative scale was granted to J. T. van Gestel. However, in a second patent [2] of the same date, van Gestel abandoned his efforts to operate the Brevoort process and introduced one of his own which, in so far as the final physical results were concerned was similar to, but not identical with, the former.

The van Gestel process consists in first thoroughly impreg-

[1] U. S. Patent, No. 653,715, July 17, 1900.

[2] U. S. Patent, No. 653,716, July 17, 1900.

nating the fabric with a solution of a soluble metallic salt, capable of yielding an insoluble oxide on electrolysis, and then placing the wet fabric between non-oxidizable electrodes and passing an electric current through it. It is claimed that there is produced from the salt an insoluble oxide in the interstices of the fabric, whereby it is rendered water-proof. As a matter of fact the insoluble oxide would be precipitated at the surface of the cathode, and a fabric in physical contact with this surface would receive and retain a portion of this precipitate, but the penetration would be relatively shallow. Since, however, the negative electrode is surrounded with a muslin covering, it would seem that with an apparatus so arranged all the insoluble oxide would remain in the muslin and little or none of it would be in the fabric being treated. No record has been found of this process having been employed on a commercial scale.

In the Tate process of electrolytically water-proofing fibrous materials,[3] not only is the fabric impregnated with a water-repelling substance, but it is claimed that the inner capillary system of the fabric is filled with this substance.

This process was first installed on an industrial and commercial basis in the autumn of 1916, in the City of Montreal, where it was operated during the war by an imperial commission; and subsequently in New York City. In July, 1920, the New York plant was transferred to Cranston, Rhode Island, where an additional equipment has been installed to provide a maximum capacity of about 30,000,000 yards per annum of electrolytically water-proofed and electrically converted fabrics.

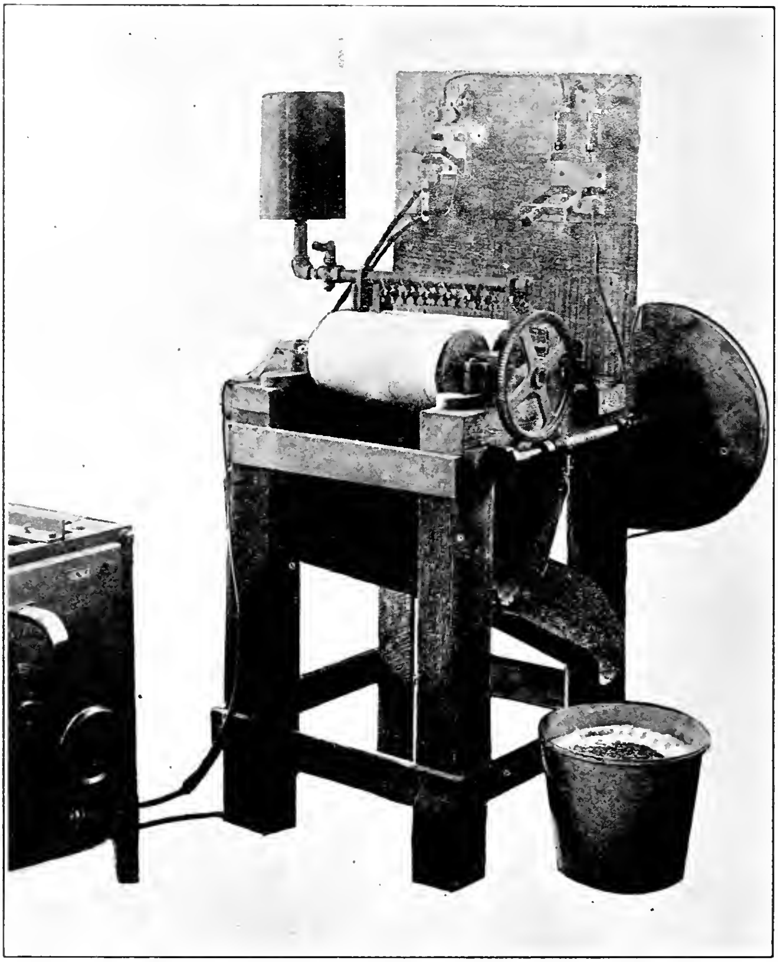
Essentially the Tate process consists in passing the fabric, previously saturated with a solution of sodium oleate, between a graphite cathode, over which flows a solution of aluminium acetate, and an aluminium anode which is completely enveloped in a heavy woolen pad. This pad is an important and distinctive feature of the invention, and before its introduction the water-proofing was quite irregular.

The historical development of the process from the original, crude, water-proofing mechanism, consisting of the small cylindrical anode and cathode shown in Fig. 1, covers four periods represented by as many types of water-proofing machines. With the first type of machine water-proofing was effected by passing the

[3] This process is covered by U. S. Patent, No. 933,861, issued September 14, 1909, and by several other patents issued subsequently.

fabric between pairs of rollers. The negative roll consisted of a cylinder of acheson graphite with electric contact through a collector brush at one end, while the positive roll consisted of a metal

Fig. 1.



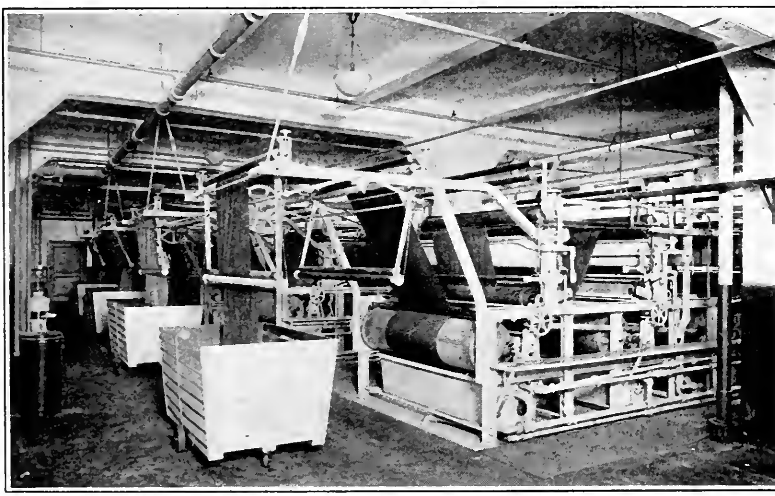
spider on which was spirally wrapped a one-inch square aluminium drawn bar. Inasmuch as a certain time period is required for the proper impregnation of the fabric, and since, furthermore, the rollers had a very small area of contact, the speed of this machine

had to be adjusted to permit of the necessary time interval for reaction. This limited the output on a single strand of fabric to about thirty-four inches per minute.

In the next commercial development, one of the roller electrodes was replaced by a stationary sector electrode for a length of contact of about five inches. In this machine the fabric was drawn between the one roller and the sector at a speed of about five yards per minute, and results obtained which were quite as satisfactory as those with the slower unit with two rollers.

In the third type of water-proofing machine, both rollers were

FIG. 2.



dispensed with and the material to be treated drawn between flat plate electrodes of aluminium and graphite, contact between the fabric and the electrodes being maintained by adjustable spring pressure. A battery of four of these machines is shown in Fig. 2. With this machine an output of about twenty-seven yards per minute was obtained as against an output of thirty-four inches with the first type of machine. Since in this unit no provision had been made for automatically relaxing the pressure when sewn lengths of fabric passed between the electrodes, the machine had to be stopped and the upper electrode lifted every time a seam came by, otherwise the fabric would tear. This difficulty has been overcome in the latest type of machine, a photograph of which (two units) is

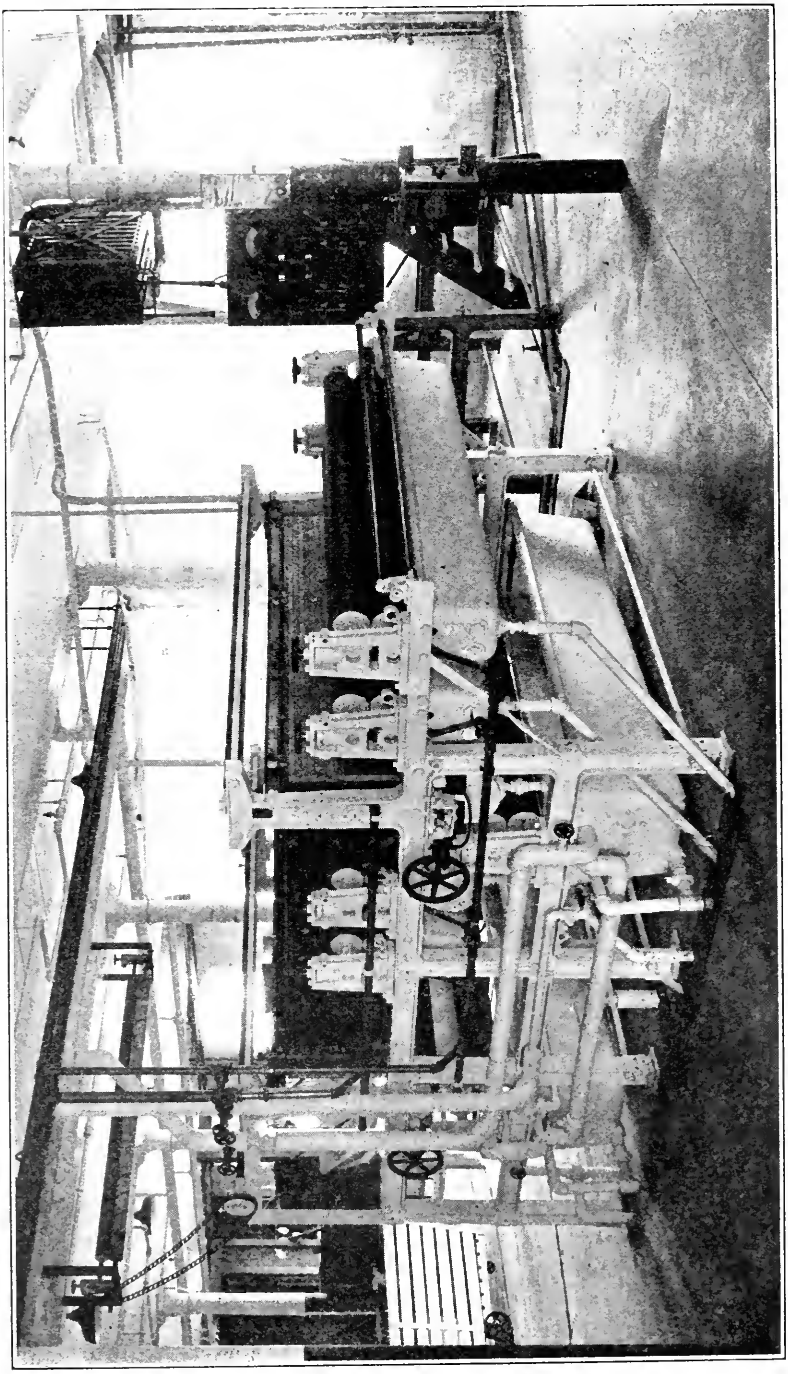
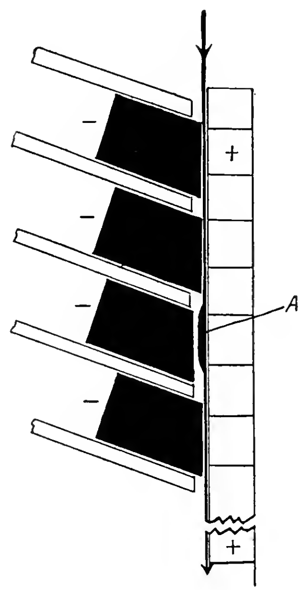


Fig. 3.

shown in Fig. 3, and a diagram (one unit) in Fig. 6. In this unit the electrodes are vertical, the anode consisting of an aluminium plate (7, Fig. 6) one inch thick by eighteen inches wide and either sixty or seventy-two inches long, and the cathode of eight graphite bars (8, Fig. 6) one and one-half inches thick by two inches wide and the same length as the anode. These graphite bars are spaced one-quarter inch apart, and their ends fit loosely between metal guides which are inclined downward toward the anode (Fig. 4).

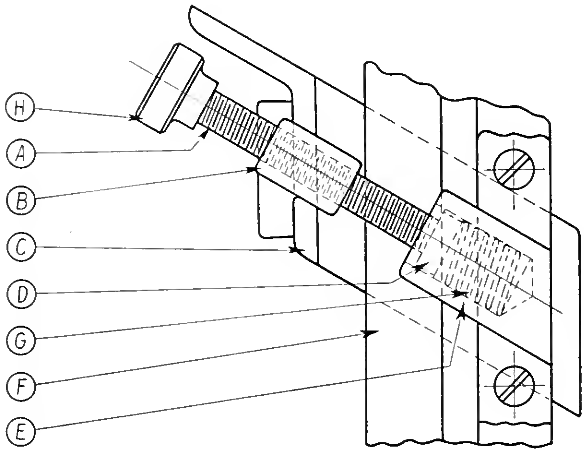
FIG. 4.



When a seam (A, Fig. 4) passes between the electrodes, each graphite bar in turn moves backward and upward and, when the seam has passed, immediately falls back to its original position. Recently a spring device (10, Fig. 6) has been installed on the vertical graphite electrodes for the purpose of permitting a delicate regulation of the pressure of each segment of the electrode on the fabric. With this device the operator can maintain a constant tension on the material being treated, regardless of its character or thickness. This regulation is very desirable and a decided improvement over the form of gravity contact, which exerted the same pressure for the finest silk or the heaviest duck. The

mechanical form of this device, shown in detail in Fig. 5, consists of a brass screw, A, threaded through a bracket, B, which is attached to each end of every graphite segment, C. The bottom end of these screws is in the form of a plunger which enters the cylinder, E, this being suitably attached to the electrode frame, F. This cylinder contains a spring, G, which is compressed by the plunger when the screw is tightened down by the small insulated knob, H.

FIG. 5.



The operation of the water-proofing process with the most recent type of machine is as follows:

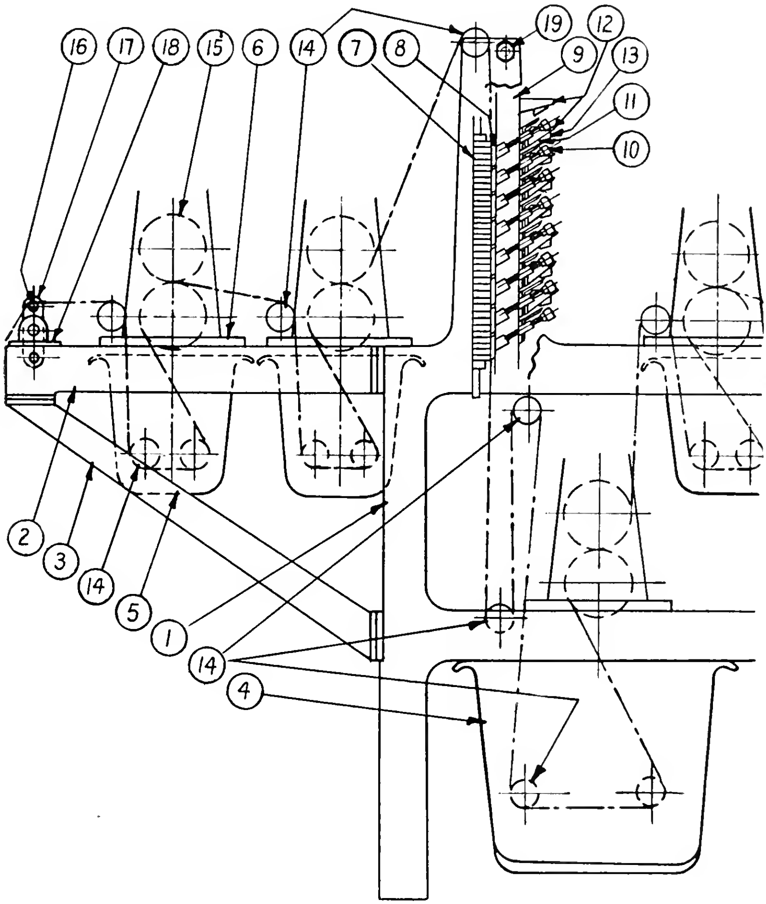
Woolens are thoroughly washed with soap and rinsed in water at a temperature of about 150° F. to remove any excess of wool grease or soap that may have been left during the process of manufacture. Cottons are all destarched by a suitable process and freed from all foreign matter. In both cases this is done with the object of cleansing the fibres and opening their capillary pores for subsequent refilling with water-repelling substances.

The fabric then enters the water-proofing machine, Fig. 6, where it is saturated with an attenuated solution of sodium oleate (preferable to sodium palmitate) contained in each of the two baths, 8. From these baths it travels up over the brass idler roll, 14, and passes downward between the electrodes, 7 and 8, between which a current of from 30 to 60 amperes flows, the current density depending upon the nature of the fabric and the character of the

treatment required. The course traveled by the fabric is shown by the broken line in Fig. 6.

From troughs, 13, connected with a suitable supply system, the aluminium acetate solution is fed between each of the one-quarter

FIG. 6.



1. Frame. 2. Frame Extension. 3. Frame extension support. 4. Wash tank. 5. Solution tank. 6. Quetch frame. 7. Anode-aluminum. 8. Cathode-graphite. 9. Graphite support-side. 10. Graphite adjuster. 11. Graphite support-end. 12. Acetate trough support. 13. Acetate trough. 14. Idler roll-brass. 15. Quetch idler roll-rubber. 16. Tension rod. 17. Tension rod holder. 18. Tension rod holder bracket. 19. Frame spreader rod.

inch openings separating the graphite segments of the cathode, 8. On coming into contact with the sodium oleate contained in the fabric, the aluminium acetate reacts with it to form an insoluble

aluminium oleate which is deposited on the surface of the fabric. A thorough and even distribution of the aluminium acetate is effected by means of a number of ducts on the contact face of each graphite segment. These ducts are cut one-eighth inch half-round at an angle of 45° with about one and one-quarter inch intervals. On each alternate segment the angles are reversed. By means of this arrangement the acetate flows down with the fabric, but while the latter moves with a vertical motion, the acetate flows down in a zig-zag path, maintaining a constant, even saturation throughout the whole electrolytic period. Additional one-quarter inch half-round ducts cut vertically about one-half inch from each end of every segment drain off the surplus acetate, thus eliminating the possibility of the insulation of the electrode supports being broken down.

When the woolen pad (not shown in Fig. 6) covering the anode, 8, first goes into action it is saturated with water, but during any given period of operation no further use of water is necessary as it then works through the saturated fabric. The active aluminium hydroxide formed at the anode is taken up by the pad and distributed evenly over the surface of the fabric, and is probably carried into the interstices of the fabric owing to kataphoresis. That the aluminium hydroxide readily passes through the pad and into the fabric is due to the fact that the suspended particles of the hydroxide are positively charged and are attracted, therefore, toward the cathode. In the van Gestel process, on the other hand, the water-repelling substance formed at the cathode cannot pass through the muslin covering to the fabric, in consequence of its attraction toward this electrode.

After passing between the electrodes, 7 and 8, the fabric then travels through the bath, 4, of running water, where it is thoroughly washed; thence to squeeze rollers immediately above the bath, to a second oleate bath, and through a continuation of the process just described, except that now the electrodes and their treatments are reversed. With cotton goods, irrespective of their weight and thickness, four treatments are essential with alternately reversed action. With silks and woolens two treatments—one reversal—are sufficient. This is due to differences in the physical structure of cotton, silk and wool fibres.

When the electrolytic treatment is complete, the fabric is

washed, dried by passing between a series of steam-heated drums, and rolled or folded.

The writer has examined and tested various kinds of textile fabrics that have been water-proofed by the process described, and has found that they possess remarkable water-resisting qualities. For example, tests on the resistance to water pressure, carried out with a thin cotton that had been water-proofed for making light-weight tents, showed that whereas the untreated cotton broke down under a water pressure of one-half inch, water did not pass through the electrolytically treated material until the pressure attained twelve and one-quarter inches. Regarding the serviceability of this water-proofed tent material, the following quotation from the letter of a camper may be of interest:

> I am enclosing a picture taken on my canoe trip down the Whitefish last summer that shows you just how useful the eight-foot square of light-weight tent cloth, water-proofed by the Tate process, which you lent me, proved to be.
>
> Coming back we struck two days solid rain, and the little water-proof patch was a wonder. We used it nights as a tent and days as a cover over our duffle, and though wet all the time, it never leaked a drop. I wouldn't have believed it possible if I hadn't slept dry as a bone under it two soaking nights.

Determination of the maximum water pressure that could be sustained by a number of samples of untreated and electrolytically water-proofed duck led to the following observations: Invariably when an untreated piece of duck broke down and water flowed through, it was found that on releasing the water pressure and re-applying it, water began to leak through the duck immediately; on the other hand, with the treated material, when the pressure was released after the water first leaked through, it was found that the pressure could again be raised to the first value before leaking recommenced. Unlike the untreated duck, when the maximum water pressure is reached with the water-proofed material the water does not leak through in one or two places but in a large number. Notwithstanding the marked water-resisting qualities of the water-proofed materials, these are found to contain but 0.3 to 0.4 gram of aluminium oxide per square foot.

In order to ascertain the efficacy of the electric current in the process that has been described, two tests have been carried out with the three following samples of very heavy duck taken from the same roll: (A) *Untreated duck;* (B) *duck that had passed through the electrolytic water-proofing machine and subjected to all*

the conditions of the normal water-proofing process, except that the electric current was not flowing; (C) *duck that had been subjected to the normal electrolytic water-proofing process. Test No. 1.* Small seamless bags of the same shape and size were made from the samples A, B, and C. These bags were suspended and the same volume of water was added to each. The water leaked through the bottom of A at the end of one and one-half seconds; through the bottom of B at the end of thirty-one seconds; while at the end of three weeks no water had leaked through C. *Test No. 2.* Portions of the samples A, B, and C were dyed under the same conditions with a dye the action of which depended on the presence of an aluminium mordant. Sample A took up but very little of the dye; sample B was dyed a deep red, and sample C a very much deeper shade, thus indicating that while the chemically treated sample B contained aluminium compounds, the electrolytically treated sample C contained much more.

It might be supposed that the fabric would be tendered by the water-proofing process. This is not so, however, as experiments show that there is an actual increase in the strength of the fabric approximately equivalent to the increase in the filature.

A study of the electrolytic water-proofing process has led to the conclusion that the water-proofing of fabrics is due to two distinct electro-chemical operations: .One, the electro-chemical formation at the anode of aluminium hydroxide which, owing to kataphoresis, is probably carried into the capillaries of the fabric; the other, the deposition on the fabric (probably only on its surface) of a film of a basic aluminium oleate resulting from the interaction of aluminium hydroxide formed electro-chemically at the cathode with the aluminium oleate produced chemically by the aluminium acetate flowing over the cathode and the sodium oleate contained in the fabric. The formation of a basic aluminium oleate, and not ordinary aluminium oleate, at the cathode, is substantiated by the fact that although both ordinary aluminium oleate and the aluminium oleate formed in the electrolytic process are insoluble in water, the former is soluble while the latter is insoluble in liquid hydrocarbons such as gasoline and benzine. Moreover, chemical analyses of the aluminium oleate scraped from the negative electrode during its formation have shown that this substance contains a considerably higher percentage of aluminium than ordinary aluminium oleate, thus proving it to be a different compound.

In addition to water-proofing, all fabrics treated by the Tate process become mildew-proof, as attested by numerous tests under conditions to which untreated fabrics invariably succumb. This feature is not attributable to any germicidal qualities of the metal salts employed, as they no not possess this property. It is due to the fact that the water-proofed fabrics receive under impact or bombardment only relatively small quantities of water, the surface penetration being very shallow, and do not, therefore, retain moisture for periods sufficiently prolonged to effect the cultivation and growth of the germ. It has been found that if treated fabrics are kept in constant contact with still water in a mildew-laden atmosphere at relatively high temperatures, they will succumb to the attack in a period of about five weeks, but this environment is rarely encountered under general service conditions. In its relation to textile fabrics of cotton manufacture, as used for tents, awnings, sails, tarpaulins and similar coverings exposed to the elements, this feature involving preservation and prolonged utility is in many instances quite as valuable as the water-repelling quality.

The influence of aluminium salts in fixing dyes is well known, and the electrolytic process, involving as it does the use of these salts, will probably fix many fugitive dyes and render them impervious to the dissolving action of water.

The electrolytic water-proofing process also performs coincidentally and thoroughly the operation of shrinking, and all fabrics thus treated are less liable to subsequent structural change of this nature through atmospheric or other action due to the influence of moisture. Microscopic examination shows that the process straightens the fibres and sets more evenly the threads or yarns of the warp and woof in fabrics wherein unevenness in this respect is present. Indeed, the changes wrought in goods of cotton manufacture bring about a complete transformation and, altogether apart from the water-repelling qualities imparted, add intrinsic value through the production of a new and better class of fabrics as judged by the recognized standards of the textile industry. This converting process does not, however, stop here. It has been found that upon calendering cotton or worsted fabrics, under ascertained conditions of temperature and pressure subsequent to water-proofing, higher surface lustres are attained than under standard finishing conditions. These lustres vary in degree from the depth

sheens usually associated only with natural silk fabrics to the brilliant surfaces which distinguish the most highly finished satins; and it is remarkable that these visual characteristics are in each instance confirmed and emphasized by the sense of touch. All of these conversions are effected without in any way impairing the water-repelling qualities originally imparted to the fabrics.

In conclusion, it will be seen that the development of the Tate process as applied to textile fabrics of all classes has advanced so far beyond the isolated achievement of rendering these materials non-absorbent, and has effected changes so entirely novel and comprehensive in their ascertained scope and potential significance, that the term water-proofing conveys a totally inadequate conception of the field which the process embraces. The electrolytic treatment represents a combined process of water-proofing and converting, while in the succeeding stage of calendering, the weave, shade, color and texture of fabrics other than woolens may be altered to predetermined degrees, producing in each instance a new and higher class of fabric, as compared with the original and as judged by recognized trade standards.

Swarthmore, Pa.,
June 17, 1921.

A Photographic Seismograph.—The seismograph is an instrument for recording earthquake shocks. The instruments in general use are so constructed that a strip of paper records any vibration, and the time of any special disturbance can be noted. The principle of construction requires a delicate adjustment of levers and amplifiers of the motion. By the introduction of sensitive paper instead of the method of inking, a simpler apparatus has been obtained, which is described by Doctor Bomet in *Photo-Pratique*. A small mirror, capable of oscillating with any earth-movement, receives a beam of light and reflects it upon a strip of sensitive paper. As the reflected ray moves through an angle which is twice that of the angular motion of the mirror, the oscillations are increased two-fold in extent. The strip of paper is, of course, kept in constant and regular movement. The mechanical construction is given in detail in the article, but need not be repeated here. Electric lamps are used for illumination. From time to time the paper strip is removed and developed and gives a clear picture of the movements to which the apparatus has been subjected. It is now well-known to experts in this field that earthquake shocks often pass through places without attracting any attention from the inhabitants. It is stated that the tremendous volcanic explosion in the Indian Ocean in 1885, by which a large part of the island of Krakatoa was destroyed, produced seven successive shocks around the earth. H. L.

X-RAY AND INFRA-RED INVESTIGATIONS OF THE MOLECULAR STRUCTURE OF LIQUID CRYSTALS.*

BY

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Government Research Fellow, James Buchanan Johnson Scholar, Johns Hopkins University, Member of the Institute.

X-RAY INVESTIGATION.

It has been shown by Lehmann and others that the optical properties of liquid crystals[1] are influenced by the surfaces between which the liquids are enclosed, so much so that Lehmann contends that "liquid crystals" have a space-lattice when they are enclosed between "similar and similarly orientating crystalline plates."

In order to bring the substance under investigation into direct contact with similarly orientating crystalline plates, a thin rectangular plate of mica was clamped along one edge and carefully split open from the opposite edge into the form of a wedge. Some finely powdered p. azoxyanisole was placed in this wedge. This wedge was gradually heated on a copper plate, and after the crystalline powder had melted the air bubbles were squeezed out at the open end. On cooling the enclosed layer of p. azoxyanisole presented a fairly uniform crystalline appearance under the microscope. This preparation was placed in the heating spirals,[2] and a series of photograms were obtained when the substance was in the solid, plastic and liquid states.

Each photogram gives the mica "point pattern" and the pattern of the substance between the mica plates. By comparing these patterns one can eliminate the mica pattern and thus obtain the pattern due to the substance only.

On transmitting a parallel pencil of X-rays through the thin solidified layer of p. azoxyanisole the pattern showed several fairly large (about 1 mm. diameter), irregularly shaped spots which indicated that the crystalline layer is made up of small crystal units of about 1 mm. in cross-section.

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* Communicated by Dr. J. S. Ames.

[1] See this Journal page 651, 1921.

[2] Ibid.

On heating the cell the crystalline layer becomes plastic. This can be tested by viewing the layer through a microscope and observing the sliding when a knitting needle is lightly pressed against one of the plates. In this state the photogram clearly shows that the substance still possesses a space-lattice. It gives a point pattern consisting of a few irregularly shaped spots, which do not give any indication of the type of crystal symmetry.

On increasing the temperature of the cell until the layer became an anisotropic liquid, and transmitting a parallel pencil of X-rays through it, a new type of pattern was obtained after an exposure of forty hours. It consists of a series of faint horizontal lines, which are about 1 mm. broad for those lines which pass through the central spot. Farther off they are fainter, thinner, and more closely spaced. If this phenomenon be due to diffraction from parallel layers of lamellar molecules the spacing between the molecules must be of the order of 40 A units. This point will be further investigated in the near future.

INFRA-RED INVESTIGATIONS.

Abney and Festing, Julius, Puccianti, Aschkinass, Rubens, Coblentz and others have shown that radicals have distinctive absorption spectra, moreover Julius, Puccianti and subsequently Coblentz have shown that the bonding of atoms in isomeric compounds has a great influence on the absorption spectrum whereas stereomeric compounds investigated by Coblentz show no change in their absorption spectra.[3]

Angström, Rubens and Aschkinass showed that the spectra of liquids and their vapors are identical, and in 1906 Pfund showed that the selective reflections from solid and from molten crystals are identical, whereas the spectrum of sulphuric acid changes with dilution.[4]

From the above-mentioned investigations it appears that any change in the molecule of a compound will be accompanied by a change in the absorption spectrum of the compound.

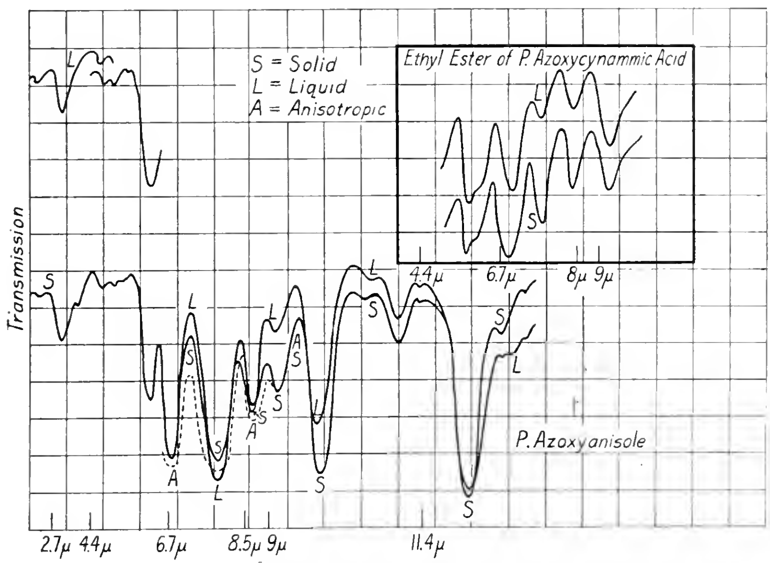
This method of investigation enables one to determine whether the absorbing mechanism of the molecule changes when it is subjected to physical changes. In order to find whether any change takes place in the molecule of those solids which give rise to liquid

[3] Coblentz: Investigations of Infra-red Spectra, Carnegie Publication 1905.

[4] *Astrophysical Journal,* 24, 1–19, 1906.

crystals in the molten state, a heating apparatus was constructed out of two concentric hollow cylinders: The inner one having a flange and a corresponding plate between which two rock salt plates containing the substance under investigation could be clamped. The outer cylinder was wound with resistance wire between asbestos sheeting. Radiations from a Nernst glower were brought to a focus by a mirror on the cell, and a second mirror projected this image on the slit of the spectroscope consisting of a Wadsworth mirror and rock salt prism arrangement

FIG. 1.



Transmission curves of p.azoxyanisole and of ethyl ester of p. azoxycynammic acid.

and a delicate thermocouple and galvanometer. A milled-head connected to a tape served to rotate the prism.

The method of procedure was to read off the galvanometer deflection when the cell was removed and when the radiations had passed through the cell and from these readings the percentage transmission was calculated. Beyond 3μ a long series of readings could be obtained without changing the slit width. This enables one to use the same portion of the cell throughout, whereas at shorter wave-lengths the cell had to be removed at frequent intervals to obtain the "air curve" for the same slit width. This method does not give concordant results with regard to percent-

ages as a small change in thickness of the layer penetrated shows a marked influence on the transmission. It does not, however, affect the positions for minima transmission.

For this work p. azoxyanisole and p. azoxycynamnic acid ethyl ester were used.[5] If any change takes place in the bonding of the atoms in the radicals one would expect to find a marked change in the spectra in the region 6μ to 10μ. From the figures it appears that the spectra of the solid, the anisotropic liquid and the amorphous liquid are the same, hence no change has taken place in the bonding of the atoms in the radicals. If changes in space-lattices be due to changes in the molecules of polymorphous substances, then these changes are not due to changes in the radicals but to a spatial rearrangement of the component parts of the molecules.

In conclusion I wish to express my sincere thanks to Professor Pfund for placing his apparatus at my disposal and also for his help and advice.

Baltimore, Md.
July 6, 1921.

Electrolytic Oxidation of the Leuco-base of Malachite Green.—The manufacture of standard coal-tar colors involves so many points of difficulty that extensive and minute research is required to obtain constancy in the product. Advance sheets of the forthcoming (40th) meeting of the American Electrochemical Society describe experiments made with a view of substituting electrolytic methods for the use of lead peroxide in making malachite green. The investigation was conducted by A. Lowy and E. H. Haux, in the department of chemistry, University of Pittsburgh. The commercial method with lead peroxide is to add this substance in slight excess, filter out the insoluble lead compound and precipitate such lead as has passed into solution by means of sodium sulphate. The equations for the reactions involved are given in detail. Experiments with an electric current showed that no satisfactory result can be obtained without a catalyst, and uranyl nitrate was found to be the best of those tried. A nichrome gauze anode in dilute sulphuric acid at 85° C. was used. A moderately high temperature is essential. The gauze dissolves in the acid which makes its use objectionable. The usual method with lead peroxide is carried out in the cold.

H. L.

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[5] These substances were kindly placed at my disposal by Professor C.W. v.d. Merwe, of Stellenbach University, South Africa.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

METALLOGRAPHIC TESTING.[1]

[ABSTRACT.]

THE value of the results of a metallographic examination as related to the testing of metals is now generally recognized. While the mere determination of certain mechanical properties may be sufficient as a routine procedure of testing, for a complete working knowledge of metals and alloys, a much more extended study, particularly of the conditions which determine the properties is necessary. The study of these fundamental conditions, structure, constitution, mechanical and thermal treatment, etc., constitute the subject of metallography, the term being used here in a broad sense and not limited to microscopic examination as was formerly the custom.

The circular discusses briefly the conditions which affect the properties of metallic materials under the following headings: Microscopy and structure, thermal analysis and heat treatment, mechanical working of metals, chemical metallurgical factors and conditions of melting.

The structure of metals is dependent upon the previous treatment the material has received as well as upon its chemical composition. Such structural features as homogeneity or the lack of it, grain size, and physical soundness of the metal, are of grave importance in determining the properties of a material. The microscopic examination has proved of great value in the study of materials which failed in service.

The thermal characteristics determine largely the heat treatment which may be given an alloy which is of such vital importance in the alloy steels in developing high mechanical properties.

Mechanical treatment is necessary for putting the material in a shape suitable for use. The properties are at the same time very materially influenced by the working and it is the effect of mechanical treatment rather than the mere shaping of the piece that is of importance in metallography.

The term "chemical metallurgy" as used in the circular is employed in a very special sense. The general metallurgical

* Communicated by the Director.

[1] Circular No. 42, 2nd ed.

processes such as the concentration and smelting of ores and the like are not discussed but the term is limited to a consideration of those features of composition, generally resulting from special treatment during preparation, which appear to have a marked effect upon the physical properties of the metal. The occurrence of gases in metals may be cited as an example.

For metals and alloys which are to be used in the cast state, the conditions attending the melting and casting of such materials are of prime importance in determining the properties of such materials. For metals which are to be given further treatment subsequent to casting the conditions of melting of the metal must also receive due consideration.

The circular summarizes the conditions under which tests of a metallographic nature will be conducted by the Bureau of Standards. Specific directions concerning shipping, sampling, etc., are given.

ZINC CYANIDE PLATING SOLUTIONS.[2]

By William Blum, F. J. Liscomb and C. M. Carson.

[ABSTRACT.]

Zinc plating or electrogalvanizing was extensively applied during the war because of the fact that zinc coatings furnish by far the best protection against corrosion of steel. Satisfactory zinc deposits can be secured from either sulphate or cyanide solutions but the latter possess the advantage of "throwing" the deposit better into deep depressions or upon the surface of irregularly shaped articles. The cyanide solutions were therefore given first consideration in this investigation. It is hoped later to extend this study to include the sulphate solutions.

It was found that satisfactory zinc cyanide plating solutions can be made by using zinc oxide to replace part or all of the zinc cyanide formerly employed for this purpose. In the analysis of such solutions zinc may be determined by the customary methods. It was not found possible to obtain by the usual methods any reliable results for either "free cyanide" or "free alkali." It is possible, however, to make fairly accurate determinations of the

[2] Technologic Paper No. 195.

total cyanide content and total hydroxide content from which data the probable constitution of the solutions can be computed.

It was found that the following conditions yield satisfactory results in practice. A solution may be prepared according to the following formulas, in which the concentrations have been rounded off to convenient values:

	Approx. normality	g/L	oz/gal
Zinc oxide	1.0	45	6
Sodium cyanide	1.5	75	10
Sodium hydroxide	.3	15	2
or			
Zinc cyanide	1.0	65	8.7
Sodium cyanide	.3	20	2.7
Sodium hydroxide	1.5	60	8

It should be operated at temperatures below 40° C. (140° F.) in order to reduce the decomposition of the cyanides. Current densities up to 3 amp/sq. dm. (28 amp/sq. ft.) may be employed upon smooth surfaces but for general work about 2 amp/sq. dm. (19 amp/sq. ft.) is preferable. The presence of large amounts of carbonate causes rough or striated deposits. Carbonates should therefore be removed from the solution at intervals by precipitation with barium cyanide or hydroxide, or by cooling the solutions to low temperatures.

RESULTS OF SOME TESTS OF MANILA ROPE.[3]

By A. H. Stang and L. R. Strickenberg.

[ABSTRACT.]

THE results of tests on manila rope discussed in this paper represent some of the data which have accumulated at the Bureau of Standards during the past few years.

Most of the specimens were submitted by various rope manufacturers on purchase orders for government departments. A fixed procedure was adopted by the laboratory for all rope tests.

The rope ranged in diameter from ½ to 4½ in. inc., and consisted of commercial three strand regular lay ropes. The breaking load, weight per linear foot, number of yarns and

[3] Technologic Paper No. 398.

the lay of the rope and strands, as well as the elongation, were measured.

The average breaking load was found to be approximately a quadratic function of the diameter of the rope. It is expressed quite closely by the equation

$$L = cd\ (d + 1)$$

in which L is the load in pounds, c is a constant equal to 5000 and d is the diameter of the rope in inches.

The ropes showed a continually varying modulus of elasticity and no well-defined proportional limit.

The number of yarns composing a rope may be expressed approximately by the equation

$$N = kd\ (d + 0.4)$$

where N is the number of yarns, k is a constant equal to 50, and d is the diameter of the rope in inches.

The test results cover sufficient range and show such consistency that it is believed that the formulas deduced may be used safely for three-strand regular lay manila rope for sizes of rope between ½ and 4½ inches in diameter.

TESTING OF THERMOMETERS.[4]

[ABSTRACT.]

THE previous edition of this circular contained, in addition to the testing regulations, much general information on thermometry and temperature measurements. The present edition has been very much shortened by including only the information which is essential to those who avail themselves of the Bureau's testing facilities.

The Bureau's standard scale of temperature is defined, and the method of reproducing it is briefly indicated. The facilities of the Bureau are such that practically all types of laboratory thermometers can be tested, but thermometers of the so-called industrial or mechanical types will not, in general, be accepted for tests because of lack of equipment for making such tests.

In testing laboratory thermometers the Bureau will usually decide upon the number and position of test points required, the choice depending upon the purpose for which the thermometer is to be used, when this purpose is known.

[4] Circular No. 8.

A new feature of the circular is the inclusion of definite test requirements and of tolerances as to correctness of graduation. Thermometers meeting the requirements as to suitable design, material and workmanship, will, if found correct within the established tolerances, be certified, others will receive reports giving the results of test. There are separate tables of tolerances for Centigrade and for Fahrenheit thermometers, and for total and for partial immersion thermometers.

Notes on the behavior of thermometers are intended to give the user of the thermometers the information necessary for an intelligent use of the results of a test. When it is recognized that the reading of a thermometer at a given temperature may be changed as much as 0.1° by a few minutes heating to a higher temperature, it is evident that the thermometer must be used under carefully specified conditions if an accuracy of 0.02° is desired.

Explanations are given of the reasons why the applicant for test must assume all risk of breakage, either in shipment or test. The circular contains general instructions to applicants for test, including instructions for packing and shipping thermometers, and the schedules of fees for testing.

General information on thermometry and temperature measurements, which was included in the previous edition of the circular, is to be incorporated, together with much new material, in a scientific paper entitled "Thermometry."

THE USE OF THE ULBRICHT SPHERE IN THE MEASUREMENT OF REFLECTION AND TRANSMISSION FACTORS.[5]

By Enoch Karrer.

[ABSTRACT.]

A BRIEF historical survey is given of the methods and instruments used in measuring the reflection factor of surfaces. Methods involving the use of the sphere are numerous. The various ways in which the sphere has been used up to recent years are briefly described. The recent applications of the sphere in a manner that affords the absolute determination of the reflection factor are also described, and several new ways of using the

[5] Scientific Paper No. 415.

sphere are pointed out. One of the new ways is given in some detail. It consists in a combination of the sphere with the Martens polarization photometer. The Martens polarization photometer enables a direct comparison to be made between the brightness of the sphere wall and the brightness of the test surface which closes an aperture in the sphere. The sphere wall is illuminated by directing a narrow beam of light through an aperture on to a spot of the sphere walls adjacent to the aperture that is closed by the sample. The sample is illuminated by the sphere wall, but is screened from the direct light from the illuminated spot. The ratio of brightness which is obtained by means of the Martens photometer is exactly the reflection factor of the test surface.

Thus the reflection factor is determined by one observation without further calculation, and without the use of a standard reflecting surface. This method may be modified so that the transmission factor may likewise be determined absolutely. The theory of the hollow sphere (commonly referred to in technical literature as the Ulbricht sphere) is given to show how this reflectometer in theory and practice conforms with it. The use of the sphere in some such manner as this is a step toward standardization.

Since the reflectometer described above resembles somewhat an instrument designed for the same purposes, but based upon the principle of the infinite luminous plane, the theory of the infinite plane is given. Sufficient discussion is given of the actual application of the theory in case of the Nutting reflectometer to show that the simple theoretical conditions are not at all attained. It is pointed out how two concentric spheres may be used instead of infinite planes.

A simple and inexpensive reflectometer is also described that may be of service for certain commercial purposes where an accuracy of 10 to 15 per cent. is allowable.

Some data are given to show that the reflection factor of magnesium carbonate in blocks as frequently used in photometry is as high as 98.7 per cent., corroborating some recent determinations by others. The value for magnesium carbonate has until recently been assumed to be 88 per cent. All blocks of magnesium carbonate as ordinarily purchasable have not as high a reflection factor. They may vary by several per cent.

SPECIFICATIONS FOR FIRE HOSE.[6]

[ABSTRACT.]

THIS specification was drawn up by the Bureau of Standards for use by government departments. The specification was submitted to the Rubber Association of America and has received the official endorsement of the Technical Committee on Specifications.

The hose purchased under the requirements of this specification is cotton rubber lined hose. The types of hose included are single-jacketed hose for use at fire hydrants, stand-pipes, and similar places, and double- and triple-jacketed hose for use on pumping engines and in places where additional wear requires increased protection afforded by the extra cotton jackets.

The chemical and physical tests to which the hose must conform are described in detail. The requirements for the rubber lining are: (1) It shall contain at least 75 per cent. by volume of the best quality new wild, or plantation rubber. (2) The organic acetone extract shall not exceed 5 per cent., and the total sulphur 8 per cent. of the weight of the rubber as compounded. (3) Its tensile strength shall be at least 1600 lb. per sq. in., ultimate elongation at least 500 per cent., and set not more than 25 per cent. after a stretch of 400 per cent. for 10 minutes after 10 minutes' rest. (4) Its lap must stand a minimum pull of 75 lb. per linear inch. (5) Its tensile strength shall be not less than 900 lb. per sq. in. after heating for 96 hours at $158 \pm 2°$ F., in order to determine the probable aging qualities.

The strength of the cotton jacket is insured by the requirements for certain measurements to be made on the finished hose when under hydraulic pressure. These measurements consist of determining the amount of elongation, twist, warp from a straight line, rise from the ground, kink and bursting pressure.

The brass couplings are governed by the requirements as to the composition of the alloy.

THE STRUCTURE AND RELATED PROPERTIES OF METALS.[7]

[ABSTRACT.]

THIS circular, which supplements one of earlier date entitled "Metallographic Testing," is a comprehensive discussion of that

[6] Circular No. 114

[7] Circular No. 113.

phase of the subject of metallography which is indicated by the above title. With but very few exceptions, the numerous illustrative examples which have been used throughout the text as types have been taken from the results of examinations of metallographic specimens submitted to the Bureau of Standards for examination and test.

In the discussion of the methods for revealing the structure of metals, the various reagents used in the macroscopic study of metals are described particularly as related to the purpose for which they are used, that is, for revealing chemical unhomogeneity, crystalline heterogeneity, physical unsoundness and mechanical non-uniformity. The principles underlying the action of etching reagents are discussed, and a list of suitable reagents for revealing the microstructure of the common industrial metals and alloys given.

Chief among the conditions which affect the structure of an alloy is chemical composition, and for any particular stystem of alloys this is graphically summarized in the constitutional or structural diagram. The structure is also profoundly affected by temperature, for example, upon heating, an alloy tends to assume a condition of physico-chemical equilibrium by diffusion, etc., so that after heating, the structure may be profoundly different from the initial state. Grain growth and phase changes upon heating are also of importance, particularly the latter, as it is to this property that the value of heat treatment as a means of obtaining wide variations in the physical properties of steel and other alloys is due. The mechanical deformation which constitutes the "working" of a metal also has a decided effect upon the structure of a metal.

In the discussion of the effect of structure upon properties, the mechanical and the chemical properties are emphasized. Some of the factors discussed which affect the mechanical properties are the presence of both hard and soft constituents such as occurs in a host of alloys, the effect of soft ductile constituents, the effect of the orientation of a test specimen with respect to the material under test, the effect of grain size, and also the physical state of any particular microscopic constituent. Typical applications of the microscopy of metals are discussed under the following heads: Relation to heat treatment, as a supplement to chemical analysis,

for controlling various metallurgical operations and products, as a necessary aid in the construction of constitutional diagrams of alloys systems, as a means for supplying important evidence bearing on the failure of metallic materials in use and on the service deterioration of certain types of alloys.

The nature of the metallurgical tests and investigations for which the Bureau of Standards is equipped is also briefly discussed.

PREPARATION OF GALACTOSE.[8]

By E. P. Clark.

[ABSTRACT.]

In preparing galactose 1500 g. of lactose are dissolved in 3750 c.c. of hot water containing 75 g. of concentrated sulfuric acid. The solution is brought to a boil and then simmered for two hours. A thin paste of barium carbonate is then added to the hot solution until it reacts neutral to Congo paper. The precipitate of barium sulfate is allowed to settle over night, after which as much as possible of the supernatant liquid is drawn off. This liquid is filtered through a thin layer of active carbon placed on moistened filter paper in a Buchner funnel. When all has passed through, the precipitate is placed on the filter, drained as dry as possible, and finally washed by drawing a little water through it. The filter, prepared with a small amount of carbon, as outlined, clarifies the solution and at the same time prevents the sulfate from passing through and gives a relatively rapid filtration.

The filtrate is concentrated under diminished pressure until it has a weight of 1650 g. If a refractometer is available the concentrated syrup should have a refractive index between 1.5120 and 1.5125. The very thick syrup is warmed to between 60 and 70° C. and 250 c.c. of ethyl alcohol are dissolved in it by vigorous shaking. The solution is then poured into a beaker or jar and the remaining syrup is washed from the flask with 500 c.c. of methyl alcohol this is done best by adding the methyl alcohol to the flask portionwise, warming and shaking in a water bath. The whole solution is thoroughly mixed, seeded with some pure galactose crystals, and allowed to crystallize.

[8] Sciertific Paper No. 416.

The crystallization is generally complete in about four days, after which the galactose is filtered off, washed with a little methyl alcohol, then with 85 per cent. ethyl alcohol, and finally with 95 per cent. alcohol. It is then dried. The yield of this crude sugar is about 27 per cent. of the lactose taken.

In order to purify the crude galactose, it is dissolved in water, making about a 25 per cent. solution. To this is added a few c.c. of glacial acetic acid. It is then concentrated under diminished pressure to about 75 per cent. total solids, warmed to 60 or 70° C., transferred to a beaker and 95 per cent. alcohol added to saturation. Almost immediately the contents of the flask become solid. After allowing to stand over night, it is filtered from the mother liquor, washed and dried. The yield is generally 82 to 83 per cent. of the crude sugar taken.

THE SPECTRAL DISTRIBUTION OF ENERGY REQUIRED TO EVOKE THE GRAY SENSATION.[9]

By Irwin G. Priest.

[ABSTRACT.]

The need of a rigidly defined standard of "white light" has long been felt, the only such "standards" in use being more or less arbitrary and without agreement among themselves. In order to be accepted as such, a standard of white light should be described in terms of the Planckian distribution of energy required to evoke the hueless sensation of brilliance commonly called "white" or "gray." Although a number of incandescent solid sources approximate in their spectral distribution of energy to the condition imposed by this formula, no source can be raised to a sufficiently high temperature to produce the sensation of white. The problem is not impossible of solution, however, for means have been found by which the spectral distribution of a source can be modified so that the distribution among the wave-lengths in the visible spectrum can be made to assume the form required by Planck's formula, for any temperature from 4000 to 7000° K, inclusive. This is accomplished by means of rotatory dispersion, produced by a system of nicols and quartz plates.

[9] Scientific Paper No. 417.

In this way a stimulus is obtained that will satisfy the most rigid requirements. The next step is to develop a suitable method from the subjective standpoint, that is, certain conditions must be satisfied under which the observer determines which ones of a given set of stimuli evoke in him the sensation of white. The chief factors are the following:

1. Fatigue effects must be avoided, by resting the eyes in the dark fully ten minutes before making observations, and by avoiding stimuli of too high or too low intensity.

2. The field of view should subtend at the eye an angle of at least 3.5° for clear vision.

3. The background should be dark, in order to avoid contrast effects.

4. The judgments should be made quickly, before the eye feels the slightest fatigue.

As the spectral distribution of the source is changed to conform with that required by the Planck formula for temperatures from 4000 to 7000° K, the color changes from yellow to white and then to blue. A suitable choice is made of six temperatures covering the transition interval from yellow to blue. The operator sets the instrument for one of these temperatures, then signals the observer to open his eyes and pronounce his judgment on the color evoked. In this way a hundred answers for each temperature have been obtained from each of four observers.

The results are shown graphically, the probability of choice as blue, white, or yellow being plotted as a function both of the (hypothetical) temperature of the source, and of the centre of gravity of the light-distribution curve corresponding to that temperature.

Another method was tried by one observer, that of changing the setting rapidly from blue to yellow or *vice versa,* in order to find the setting for white. This method involves a change in intensity of the stimulus, and is not so satisfactory as the other method.

On account of the small number of observers involved, no general conclusions can be drawn from the data obtained. The results of one observer are different from those of the other three, due perhaps to a defect in the cornea, or a decided difference in visibility, or a difference in age. The conclusion to be drawn from the observations of the other three is that the hypothetical

temperature of the source (conforming to the Planckian energy distribution) that evokes the sensation of gray is about 5200° K. The centre of gravity of this light distribution is 560.4 millimicrons, or approximately the same as average noon sunlight. The results are compared with previously proposed standards for average daylight.

This investigation can be regarded only as preliminary, due to the small number of observers concerned. But the "method of answers" has been demonstrated as perfectly reliable, and there seems no reason why, with a greater number of observers, the problem of a standard of white may not be solved.

SPECTRORADIOMETRIC INVESTIGATION OF THE TRANSMISSION OF VARIOUS SUBSTANCES, II.[10]

By W. W. Coblentz.

[ABSTRACT.]

This paper gives transmission data in the spectrum extending from 0.6μ to 3μ, using a mirror spectrometer, a quartz prism and a vacuum thermopile. The substances examined are a group of mineral, animal and vegetable oils (containing fatty acids), nitrocellulose, bakelite and selenite. It is shown that the absorption spectra of the oils are so nearly identical that they cannot be used for detecting the adulteration of one oil with another. The paper concludes with an examination of the accuracy of the author's previous work, using a rock salt prism. It is found that, using the recently determined refractive indices of rock salt, the corrections to the observations of 1903 to 1905 are of the order of 0.01μ to 0.02μ and hence negligible.

THE DESIGN OF ATMOSPHERIC GAS BURNERS.[11]

By Walter M. Berry, I. V. Brumbaugh, G. F. Moulton and G. B. Shawn.

[ABSTRACT.]

The Bureau of Standards has carried on an extensive investigation of gas burner design, intended primarily for the benefit of manufacturers of gas appliances and industrial gas appliance

[10] Scientific Paper No. 418.

[11] Technologic Paper No. 193.

engineers. No extensive presentation of theory has been attempted, the aim being rather to show by means of tables and curves, representing experimental data, the effect of the various factors on the operation of burners.

With the arrangement of apparatus and method of testing that has been developed one can measure quickly and accurately the volume of air injected into any burner under any condition of operation, as well as determine the limits of operation with any quality of gas. Such information is essential in order to enable one to design burners for any predetermined condition of operation.

In order to understand the various factors entering into the design of burners it was found necessary to study the theory of flow of gas through different types of orifices, the principles governing the rate of injection of air into the burner, the design of the injecting tube, the rate of consumption of burners of different port areas, and the effect of adjustment of the air shutter.

THE ORIFICE.

The orifices have been divided into two classes—the "channel" type, which has some thickness between the inner and outer wall at the point of discharge, and the "sharp edge" type, in which the inner and outer walls come to a sharp edge at the point of discharge.

1. *Discharge Coefficient of Orifices.*—The discharge coefficient of a sharp edge orifice with a given angle of approach is a constant for ordinary sizes of gas orifices and over the usual range of gas pressures. When the discharge coefficient was determined for sharp edge orifices with different angles of approach it was found that it varies from about 0.605 for a 90° approach to about 0.875 for an 8° approach.

It was found that with orifices of the channel type the coefficient will vary not only with a change in the angle of approach but also with a change in the length of channel and the pressure of the gas.

2. *Loss of Air Injection with Different Types of Orifices.*—With the sharp edge types of orifices the friction loss was found to be exactly the same for all designs. The friction loss of the channel type varies with the length of channel and is greater than the friction loss of the sharp edge type.

3. *Rate of Flow Through Orifices.*—If the rate of flow of gas through an orifice is desired, or the size of orifice is required for any given gas rate, it is necessary to know the gas pressure, the specific gravity of the gas, and the discharge coefficient of the orifice. The following formulas will enable one to calculate readily any one unknown value by substituting in the formula the known values.

$$Q = 1658.5\ KA\sqrt{\frac{H}{d}} \text{ or } A = \frac{Q}{1658.5\ K}\sqrt{\frac{d}{H}}$$

where Q = rate of flow through orifice in cubic feet per hour;
A = area of orifice in square inches;
K = orifice constant, or discharge coefficient;
H = orifice pressure in inches of water;
d = specific gravity of gas (Air = 1.0).

PRINCIPLES GOVERNING AIR INJECTION.

From the fundamental theory and the relations which have been illustrated by examples it is possible to summarize the most important relations as follows:

1. The ratio between the momentum of the gas stream and the momentum of the stream of the mixture is always the same for a burner of a given design irrespective of orifice pressure, specific gravity of gas, or the volume of the air and gas mixture going through the burner.

2. Where the gas rate is increased by change of pressure, the momenta of the gas streams are directly proportional to the pressures.

3. When the same volumes of gases of different specific gravities issue from different orifices under the same orifice pressure the momenta of the gas streams are proportional to the square roots of the specific gravities of the gases.

4. When the pressure is changed to give the same gas rate for gases of different specific gravities, the air entrainment is proportional to the specific gravities.

5. The pressure at any one point in the burner increases in direct proportion to the increase in the momentum of the stream of the mixture.

If the volume of air injected into a given burner for a gas of a given specific gravity at a given pressure and the gas rate is known, it is possible to calculate from the above stated relations

the volume of air injected with a gas of any other specific gravity, gas rate, or gas pressure.

THE INJECTING TUBE.

The advantages of using an injector of good design to increase the injection of primary air has been illustrated by tables and a large number of curves. The general design of an injecting tube that produced the greatest injection of primary air was determined. If it is impracticable to use injectors of the best design because of limitations in the size of the burners, it is possible to determine from the tables and curves which are given the relative injecting power of other designs.

It is very important that there should be a definite relation between the area of the throat of the injecting tube and the port area of the burner if the energy of the gas is to be efficiently utilized to inject air into a burner. The results of the tests show that the area of the injector throat should be about 43 per cent. of the area of the burner ports.

BURNER TUBE AND BURNER PORTS.

In the section on the burner tube the characteristics required in a satisfactory burner have been discussed. For burners without injecting tubes it has been shown how the rate of consumption per square inch of port area increases with increase in the port area. The rate of consumption of burners with injecting tubes has been shown in the same way. From the tabulations and curves the rate of consumption per square inch of port area corresponding to an average burner has been determined, and tables have been prepared which show the rate of consumption of various sizes of burners for different gas pressures.

THE AIR SHUTTER.

The velocity of the air through the air opening will depend upon the area of the air opening, the momentum of the gas stream issuing from the orifice, the area of the burner ports, and the design of the injector. For the greatest injection of air the opening in the air shutter must be large enough to allow a free and unrestricted flow of air into the burner. From a few curves that have been shown it seems that the area of the air opening should be of such size that the velocity of the air through the opening does not exceed 4 or 5 ft. per second.

CONCLUSION.

On account of its simplicity, low cost, and reliability the atmospheric burner is well adapted for domestic and most of the smaller industrial purposes. If it is possible to widen the range within which such burners can be operated efficiently and without adjustments, and design them to meet the needs of any particular purpose, it will make gas fuel much more valuable and will broaden its field of application. With this in view the Bureau of Standards has been conducting experiments upon the efficiency and performance of atmospheric burners, both with natural and artificial gas, and the results will be reported in subsequent papers.

HIGH FIRE PORCELAIN GLAZES.[12]

By H. H. Sortwell.

[ABSTRACT.]

THIS work consists of the investigation of a wide range of high fire porcelain glazes of the Seger cone formula type to determine the limits wherein lie glazes suitable for high fire porcelain, chemical porcelain, spark plugs, pyrometer tubes, etc., maturing at temperatures of from Seger cones 12 to 16. The field was studied from the standpoint of fusbility and of commercial acceptability as glazes.

Compositions Studied.—The RO of all of the glazes was maintained constant at 0.7 equivalents CaO and 0.3 equivalents K_2O. The variations were in the SiO_2 and Al_2O_3 contents, the SiO_2 varying from 3.0 to 13.0 equivalents and the Al_2O_3 varying from 0.3 to 3.25 equivalents between the alumina : silica ratios of 1 : 4 and 1 : 20. This covered the field with fair uniformity when plotted both by empirical formulas and by batch weights.

Methods Employed.—The glazes were weighed separately and ground in small ball mills three hours. A small quantity of each glaze was evaporated to dryness and moulded into test cones. The deformation temperatures of the cones were determined in a small gas furnace. Check determinations were made to within 5° C. The temperature was raised at the rate of 50° C. an hour above 1100° C.

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[12] Technologic Paper, No. 196.

The glazes were applied to porcelain cups which had been biscuited to cone 08. The composition of the body was 31 North Carolina kaolin, 12 Florida kaolin, 5 Tennessee ball clay, 34 flint and 18 feldspar.

Four glaze burns were made in a gas-fired kiln, to cone 10 in 20 hours, to cone 12 in 20 hours, to cone 14 in 22 hours, and to cone 16 in 24 hours. Reducing conditions were maintained to cone 8, but from that point allowed to diminish until the fire was neutral or slightly oxidizing at the finish.

Deformation Temperatures.—The deformation temperatures of the glazes were from 1100° C. to 1400° C. The fusibility of the entire field is shown graphically by isotherms, plotted both by empirical formulas and by batch weights.

There is a deformation eutectic axis lying at a slight inclination to the ordinate representing Al_2O_3 between 0.55 and 0.60 Al_2O_3, up to 7.0 equivalents of SiO_2. As the SiO_2 content approaches 7.0 equivalents this inclination rises and at 11.0 equivalents silica it increases much more.

Starting with 0.3 Al_2O_3 and any SiO_2 content increasing the Al_2O_3 lowers the deformation temperature until the deformation eutectic axis is crossed. Further increase in Al_2O_3 increases the deformation temperature.

Increase in silica content up to 11 equivalents has little effect in comparison with Al_2O_3 in increasing the deformation temperature. Beyond this figure further increase in SiO_2 increases the deformation temperature more rapidly.

Glaze Burns.—At cone 10 the number of good bright glazes is comparatively small and they are surrounded successively by semi-mat, mat, and immature glazes. Crazing occurs when the alumina content of the glazes is low.

Increase in the burning temperature increases the number of good bright glazes, causes a proportionate shift in the location of semi-mat and mat glazes and reduces the number of immature glazes. With increase in burning temperature, the occurrence of crazing is reduced. Overburning occurs in the more fusible glazes as the temperature increases.

Increase in Al_2O_3 in this type of glaze corrects crazing. Increase in SiO_2 will not correct crazing, but if increased sufficiently may cause it to occur.

The best glazes are higher in Al_2O_3 content than the most fusible glaze with the same amount of SiO_2. The most fusible glazes with a given silica content above 7.0 equivalents craze.

The results of the glaze burns are plotted graphically showing the location of the best glazes at the different temperatures, the location of mat and semi-mat glazes and the occurrence of crazing.

There is a wide range of commercially acceptable bright glazes of this type with a heat range of from 4 to 5 cones. The best glazes for cones 12 to 16 with the RO of 0.7 CaO and 0.3 K_2O fall under the approximate formula:

$$Al_2\,O_3 = 0.3 + 1/12\ Si\,O_2$$

The fusibility may be controlled by varying the SiO_2 from 4.0 equivalents for cone 12 to 10.0 equivalents for cone 16, with the Al_2O_3 content indicated by the formula.

STANDARD SPECIFICATIONS FOR LARGE INCANDESCENT ELECTRIC LAMPS.[13]

[ABSTRACT.]

FOR about fourteen years electric lamps have been purchased by the Federal Government under specifications published in Circular 13 of the Bureau of Standards. Progress in the art of lamp manufacture has been so rapid that this circular has to be revised eight times in order to keep the specifications abreast of current developments. The original specifications covered only carbon filament lamps. In later editions metallized carbon and tantalum lamps were introduced and then discarded, as tungsten filament lamps gradually displaced them in use. In connection with these radical changes in types of lamps, very great improvements were made in the efficiency and the life required, but no fundamental change was made in the form of the specifications or in the methods of testing.

For the fiscal year beginning on July 1, 1921, new specifications have been adopted, which include important changes in the test procedure for tungsten lamps.

The most notable of these changes is the abandonment of the long-established provision that the life of test-lamps shall be considered as ended when the candlepower has fallen to 80 per

[13] Circular No. 13, (9th edition).

cent. of the initial value. The specification of such an end-point is convenient and reasonable in the testing of carbon lamps because those lamps will often burn for a long period after they have become so blackened that they should not be continued in use. In tungsten lamps, however, means have been found to prevent excessive blackening of the bulbs, so that the lamps normally burn out before their efficiency has fallen enough to justify replacing them. The new tests will therefore be based on the total life to the time of burn-out, thus conforming more nearly to actual practice in the use of lamps.

The performance of the lamp throughout its life will also be taken into account through two new provisions. One of these is the evaluation of life-test results on the basis of average efficiency throughout life, instead of the initial efficiency; the other is a requirement that the average light flux during the life of the lamp must not fall below a specified percentage of the initial flux.

Another new feature is the establishment of tolerances to allow for possible variations in test results arising from the fact that small numbers of test samples may not represent fairly the average quality of the lamps from which they are selected.

On account of the desirability of standardizing a small number of voltage ratings, the tungsten lamp schedules recognize specifically only the five- and ten-volt steps instead of the former voltage ranges. It is understood that for the present lamps of other voltages within the usual range will be furnished under the same specifications, but users will ultimately find it advantageous to bring their circuits to one of the standard voltages.

Tests under these new specifications are intended to give a more complete indication of the performance of lamps than the former specifications did, and thus to discriminate more exactly between types of lamps. In the first application of the new specifications it has, however, been deemed wise to make the requirements moderate. The numerical values in the tables of requirements are based on extensive studies of the performance of lamps in tests made by various manufacturers as well as by the Bureau of Standards. It is believed that they have been so adjusted that the change in specifications will involve no injustice either to lamp manufacturers or to purchasers. The carbon-lamp schedule has been retained because these lamps still find some use,

but the specifications for them are practically unchanged from those given in previous editions of this circular.

These specifications have been prepared primarily for the use of the departments of the government in purchasing incandescent lamps, but it seems desirable, on account of the thoroughness with which the subject has been studied and discussed, that the specifications should be available to the general public. They are, therefore, being issued as the ninth edition of Bureau of Standards Circular No. 13, and copies may be obtained on application to that Bureau. Criticisms and suggestions concerning these specifications and lamp ratings are invited from both manufacturers and users of lamps. All such suggestions will be carefully considered when the specifications are again revised.

A Reciprocating Apparatus for Detecting Ionizing Rays. Takeo Shimizu. (*Proc. Roy. Soc.*, A. 700.)—Mr. C. T. R. Wilson, of Cambridge, years ago devised a very elegant method of making visible the paths of ionizing particles in gases. Air containing water vapor was expanded suddenly and the vapor condensed upon the ions. The path of an alpha particle was a streak of cloud, the droplets of which had formed around the ions caused by the collisions of the particle. Mr. Shimizu has modified the method so that the expansion is produced twice a second along with the application of an electrostatic field for a known part of the stroke. A reciprocating mechanism operates the piston governing the expansion.

For a study of the path of each track the Wilson apparatus is superior. It is, however, claimed that the newer form is more sensitive and by the periodic recurrence of the stroke it is possible to study the time of the origination of the rays producing the traces.

Mr. Shimizu has used his device to investigate the products of collisions with alpha particles. Sir Ernest Rutherford states that among 100,000 alpha particles from radium C passing through air there will be one making close collision with an atomic nucleus so as to produce a rapidly moving atom. A moving picture film recorded the tracks as seen from two positions at right angles to each other. In the 3000 tracks photographed 35 spurred tracks were found, but their explanation and interpretation remains for the future.

Owing to this recently devised apparatus it has thus become possible to have a registration at half-second intervals, if not continuously, of what goes on in air subject to the bombardment of ionizing particles. This field of investigation is thereby advanced to an extent comparable to the progress introduced into other fields upon the employment of continuously recording methods.

G. F. S.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, September 7, 1921.*)

Hall of the Institute,
Philadelphia, September 7, 1921.

Mr. Charles W. Masland *in the Chair.*

The following report was presented for first reading:

No. 2768. "Once-Over" Tiller.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, September 14, 1921.*)

RESIDENT.

Mr. Roland L. Andreau, Laurel Springs, New Jersey.

Mr. Arthur Knapp, United Gas Improvement Company, Philadelphia, Pennsylvania.

Mr. Stephen H. Noyes, Civil Engineer, Room 746, City Hall, Philadelphia, Pennsylvania.

Mr. Rufus H. Sanford, Librarian, The Baldwin Locomotive Works, Philadelphia, Pennsylvania.

Mr. Howard Stoertz, Electric Storage Battery Company, 19th Street and Allegheny Avenue, Philadelphia, Pennsylvania.

Mr. Solomon Weinberg, Sunderland House, 35th Street and Powelton Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

Mr. Arthur Blackburn, 5905 York Road, Baltimore, Maryland.

Mr. E. Z. Crow, P. O. Drawer, 428, Chickasaw Branch, Mobile, Alabama.

Mr. John Stuart Eason, 819 University Avenue, N. E., Minneapolis, Minnesota.

Mr. William H. Gesell, 235 Christopher Street, Montclair, New Jersey.

Dr. W. J. Humphreys, Weather Bureau, Washington, District of Columbia.

MR. D. BRUCE MORGAN, 805 Gotham National Bank Building, New York City, New York.

CHANGES OF ADDRESS.

MR. CARL P. BIRKINBINE, Commercial Trust Building, Room 800, Philadelphia, Pennsylvania.

MR. HENRY M. ELLIOT, 5 Northern Boulevard, Albany, New York.

MR. RUDOLPH HERING, 40 Lloyd Road, Montclair, New Jersey.

DR. HARRY F. KELLER, 103 W. Upsal Street, Germantown, Philadelphia, Pennsylvania.

MAJOR C. W. MCMEEKIN, 1632 Spruce Street, Berkeley, California.

MR. LEGRAND PARISH, President, American Arch Company, Inc., 17 East 42nd Street, New York City, New York.

PROFESSOR I. M. RAPP, State University, Missoula, Montana.

DR. W. F. RITTMAN, care of Carnegie Tech., Pittsburgh, Pennsylvania.

MR. JOHN STONE STONE, 4811 Panorama Street, San Diego, California.

MR. J. STEPHEN VAN DER LINGEN, Physical Laboratory, The Johns Hopkins University, Baltimore, Maryland.

NECROLOGY.

Charles Otis Bond was born in Iowa, in 1871 and died at Collegeville, Pennsylvania, August 2, 1921.

He was graduated from the United States Naval Academy and served as a lieutenant during the war with Spain. He became associated with the United Gas Improvement Company in 1897 and was for a number of years the the head of the physical and photometrical laboratory of the Company at Point Breeze. During this time he specialized in standardizing apparatus for testing the heating and illuminating qualities of gas and invented improved devices for this purpose, one of which, a "dewpoint" hygrometer, is of special value for determining the lowest temperature that gas reaches in the mains.

Mr. Bond became greatly interested in the subject of illumination and was known as an authority on gas as an illuminant. This was recognized by his election as national president of the Illuminating Engineering Society in 1914.

He became a member of The Franklin Institute in 1903.

Henry F. Colvin was born at Plainfield, Connecticut, on July 6, 1838 but at an early age his family removed to Scott, Pennsylvania. While still a youth he was for a time engaged with his father in the gunsmithing business. When he was eighteen years old, he entered the employ of the Delaware, Lackawanna and Western Railroad and three years later became an engineer on the same road. Finding locomotive running too great a physical strain, he retired from the service and connected himself with one of the large locomotive manufacturing plants of New England. In 1876, he associated himself with the Rue Manufacturing Company of Philadelphia and two years later removed to Philadelphia and became general manager of the company, which position he held for over thirty years, until his retirement from active life.

NOTES FROM THE LABORATORY OF APPLIED SCIENCE, NELA RESEARCH LABORATORIES.*

RHYTHMIC DEPOSITION OF PRECIPITATED VAPORS.[1]

By E. Karrer.

[ABSTRACT.]

RHYTHMIC deposition of ammonia hydrochloride is observed when ammonia and hydrochloric acid vapors are allowed to mix by diffusion. Good results are obtained when the vapor of ammonia diffuses into the vapor of hydrochloric acid contained in rather small vials which are well protected from ordinary atmospheric disturbances. The rhythmical deposits in such vials may be separated by more than a centimetre or by only a fractional part of a millimetre. In fact, the fineness of the resulting laminar structure may almost go beyond that detectable by the unaided eye. Observations are recorded which show that a temperature-gradient laterally is necessary. The phenomenon is very closely related to that recently studied by Mendenhall and Mason, who showed that the striæ in sedimentation are brought about by the convection currents in the liquid resulting from a lateral temperature-gradient. It is also pointed out that the stratification in gases may be of importance in meteorology as is the stratification of sediment in geology, and as is the Liesegang phenomenon, *i.e.*, rhythmic precipitation in gels, in biology.

The stratification of gases frequently observed by gas engineers, both in large as well as in small containers, may be referable to this phenomenon.

THE SHAPE ASSUMED BY A DEFORMABLE BODY IMMERSED IN A MOVING FLUID.[2]

By E. Karrer.

[ABSTRACT.]

GENERAL considerations are given of how a deformable body will change its shape in a moving fluid. On certain phases of this question considerable work has been done in aeronautics; as for

* Communicated by the Director.

[1] To be published in the *Jour. American Chemical Society*.

[2] To be published in this Journal.

example, the resistance encountered by a body of definite shape when moving in air or water; and the distribution of pressure over the surface of the body when moving in air (wind-tunnel experiments).

The theme of the present work is that a body, immersed in and in relative motion with a fluid, will assume as nearly as possible a shape such that contour lines are stream-lines. Observations on a mercury drop are given to substantiate this theme. Illustrations are also gathered from many realms of science—geology, biology, physics, meteorology.

In biology the importance of the adjustment of shape to stream-line contours seems sufficiently great to be designated by a term (rheotropism), for this phenomenon is parallel to others where the organism adjusts itself to a field of directed stimulus, as geotropism, heliotropism, and galvanotropism.

COMMENTS ON THE THEORY AND PRESENT STATUS OF FLICKER PHOTOMETRY.

By A. H. Taylor.

[ABSTRACT.]

THE flicker photometer has been used to some extent in heterochromatic photometry, to avoid the difficulties usually encountered in photometering lights differing greatly in color. However, its more general adoption has probably been retarded by a lack of understanding of its theory, and by practical difficulties encountered in its operation. This paper gives a simple treatment of the theory from a new point of view, and gives references to published data bearing upon it. It also points out some requirements for satisfactory operation of such photometers. Full details will soon be available in the *Transactions of the Illuminating Engineering Society*.

PAINTS FOR INTEGRATING SPHERES.

By A. H. Taylor.

[ABSTRACT.]

MANY photometric integrating spheres for measurement of light flux are in use in this country, but considerable difficulty

has been encountered in obtaining a satisfactory white paint which was tenacious and permanent in color. An investigation carried out by the author at the Bureau of Standards several years ago resulted in a very satisfactory paint. The formula for the paint, together with full details as to preparation and use, will soon be published in the *Transactions of the Illuminating Engineering Society.*

CLEVELAND, OHIO,
August 16, 1921.

Stereoscopic Portraits.—*Das Atelier des Photographen* has an article on this subject, referring to an invention made in 1853, by a Philadelphian, J. F. Mascher, who took out a patent in that year for an "Improvement in Daguerreotype Cases." The main feature of his invention was the provision of a small convex lens attached in a movable flap to the case containing the picture so that it could be viewed somewhat magnified, but the special feature was the making of two portraits by stereoscopic methods and providing a pair of lenses for securing the effect. The German writer figures the apparatus, and states that the pictures show an exaggerated solidity, and were probably made by a collodion film on glass, being, therefore, of the nature of the ambrotype, which was much in vogue prior to the introduction of the paper positive. A picture of the apparatus is given. It is interesting to note that one of the stereoscopic portraits is in the possession of The Franklin Institute. It was evidently made by a stereoscopic camera, for the two pictures have noticeable, though slight, differences and when viewed with the lenses show a strong, indeed excessive, solidity. The claim in the patent does not specifically refer to the application of stereoscopy, and the inventor put on the market many cases with single pictures. The attention given to the matter indicates that the Germans, like the French, are taking much interest in the revival of stereoscopic work, a special field which has been the subject of a good deal of discussion lately in the projection on the screen of the effect of solidity.

H. L.

The Manufacture of Optical Glass.—This problem has received a great deal of attention of recent years. The dependence of the world at large upon Germany for glass suitable for the construction of many optical instruments for warfare and research was brought to notice when the war broke out, and it became necessary for the other belligerent nations to establish industries for the purpose. The subject is revived by the publication of a pamphlet by the Goerz Company, being a reprint of an article by Dr. F. Weidert (of the

Goerz Company) originally appearing in a Berlin engineering journal. The article is illustrated with eight full-page plates, giving views of certain parts of the factory of that firm. The title is "Herstellung und Eigenschaften des Optischen Glasses." One point of interest is the statement that just before the breaking out of the war, only three establishments capable of producing optical glass existed. These were: Chance Brothers in England, Parra-Mantois in France and Schott and Company in Jena. The product of the English firm was principally for mirrors, of which it was the largest European manufacturer, but its true optical glass was in small amount. The Paris firm produced a high-class material but not in large amount. The Jena firm was not deemed sufficient for the needs of Germany, and shortly before the war another German establishment was founded. The pamphlet gives an account of the principal features of the establishment of the German glass industry, in which the familiar names of Steinheil and Fraunhofer appear. H. L.

New Determinations of the Density of the Air at Geneva. A. TREUTHARDT. **On the Density of the Air at Madrid and its Slight Variations.** MOLES, BATUCCAS AND PAYA. (*Comptes Rendus,* June 20, 1921.)—Contrary to the general belief the density of the air under standard conditions is not strictly constant. At the same place it appears to be less by some tenths of a milligram per liter during periods of high barometric pressure. This was shown to true for the air of Geneva by Guye and his collaborators in 1910, and was confirmed two years later for the same place and six years later for Cleveland, Ohio. Near a pressure of 760 mm. flasks were filled with air at zero from which water vapor and carbon dioxide had been removed. The previous results were confirmed by the Swiss as well as by the Spanish observers. The latter plotted both the changes in barometric height and in density for considerable part of a year. It is noteworthy that when one of these changes increases the other decreases almost unfailingly. At one period of apparent exception to this statement the weather was clear and the sunshine strong. This led to the suspicion that ozone might be the cause of the divergence. When the air was treated in such manner as to free it from ozone its density was found to cease to be exceptional.

The average of the determinations in Geneva was 1.29269 per liter and in Madrid 1.29303. In view of the outcome of the experiments it is suggested that air should not be used as a standard for getting the densities of other gases.

The quantities concerned are, to be sure, small, but let it be remembered that other minimal differences of density led to the discovery of argon.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

A CRITIQUE OF MR. RENWIK'S THEORY OF THE LATENT IMAGE.[1]

By S. E. Sheppard.

[ABSTRACT.]

MR. F. F. RENWICK has proposed a theory of the latent image according to which developability is due not to a photochemical decomposition of the halide, but to the coagulation by light of preëxistent colloidal silver nuclei (due to ripening) to coarser-grained nuclei capable of functioning as development germs. In the criticism it is pointed out that experiments on the direct action of light in lowering the dispersity of colloidal silver in aqueous solutions do not lend support to this hypothesis, as the sensibility does not seem sufficient. It is argued that a photochemical development of the original nuclei by decomposition of the silver halide is essential, and the function of colloid silver as a specific photochemical autocatalyst for this photolysis is discussed.

THE SIZE-FREQUENCY DISTRIBUTION OF PARTICLES OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTERISTICS.[2]

By E. P. Wightman and S. E. Sheppard.

[ABSTRACT.]

C. E. K. MEES, in a paper on "The Physics of the Photographic Process," had pointed out the possibility of a relationship between size-frequency of grains in a photographic emulsion and the characteristic D-log E curve for that emulsion. The relations suggested, however, were speculative.

Experimental work was begun on the problem in 1919. In the meantime Slade and Higson, and T. Svedberg have published

* Communicated by the Director.

[1] Communication No. 113 from the Research Laboratory of the Eastman Kodak Company, published in *B. J.*, Jan. 7, 1921, p. 4.

[2] Communication No. 103 from the Research Laboratory of the Eastman Kodak Company, published in *J. Phys. Chem.*, March, 1921, p. 181.

some work along the same line. The former believe that γ infinity is increased by homogenizing the grain and that latitude is diminished. The latter, working with dilute emulsions one-grain layer thick, obtained (a) curves connecting exposure and percentage reduced grains for each order of magnitude of the grains, (b) curves showing the relation between size of grain and percentage made reducible after a certain exposure. The first type of curve is comparable with the characteristic curve; the second gives the relation of light sensitiveness of size of grain. It appears from this work that every class of grain has its own characteristic curve.

The authors of the present paper have calculated the actual D-log E curves for the four classes of grains used by Svedberg by means of a relationship assumed by Higson to exist between the size of the developed grain and its photometric constant. The results of this calculation indicate a fallacy in Higson's assumption that the developed grain has twice the diameter of the original undeveloped grain. This is shown by a comparison of the summation curve of the values for each class size (based on the assumption that the developed grains in Svedberg's work were not twice, but approximately the same diameter as the undeveloped grain) with the experimental D-log E curve for the Svedberg emulsion. A size-frequency distribution curve plotted from Svedberg's data shows that by far the largest number of grains in his emulsion had a mean projective area less that 75 sq. mm. $\times 10^{-8}$.

COLLOIDAL FUELS, THEIR PREPARATION AND PROPERTIES.[3]

By S. E. Sheppard.

[ABSTRACT.]

THIS paper was given at the Fuel Symposium of the American Chemical Society Convention at Chicago, 1920. Applications of colloid chemistry to the fuel problem are discussed, and a description given of a new class of liquid and semi-liquid fuels. These were developed in the Laboratory in the last two years of the war, following a suggestion of Mr. J. G. Capstaff and in coöperation with the Submarine Defense Association, and consist

[3] Communication No. 101 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. Eng. Chem.*, January, 1921, p. 37.

of various forms of finely divided carbon stably suspended in fuel oil. The application of Stoke's law is discussed, and also, the development of fixateurs or stabilizers from lime soap greases, the solvent and chemical peptization of coals, and methods of incorporation and testing. A summary of results in large scale marine and power house trials is given and a survey of the characteristics of the fuels in the direction of economizing oil fuel, then menaced by the German submarine campaign.

THE MEASUREMENT OF COLOR.[4]

By C. E. K. Mees.

[ABSTRACT.]

THE methods of measuring color fall into two distinct classes, according to whether we wish to measure the sensation of the color produced upon the observer or the means by which that sensation is produced. When we wish to study the finished product, we need to measure the sensation; thus, if we are manufacturing ribbons of a definite shade, a method of measuring and specifying that color is necessary. But if we are dyeing ribbon, we shall be doing it by means of dyes, and it is necessary to have a method of measuring the amount of coloring power which the dyes have. This should be done independently of the color which they produce upon the goods when they are finished and in terms which can be translated at once into the weight of dye which it is necessary to use.

When measuring the amount of material which produces the sensation of color, we must use analytical methods owing to the composite nature of the light with which we have to deal, while when we are dealing with the sensation of color produced, synthetic methods of measurements must be employed. The analytical instrument used for the measurement of the amount of material which produces a given color is termed the "spectrophotometer," and by means of it the curves of absorption of light by the dye can be obtained, and from those curves the amount of coloring matter present can be read directly.

The instrument for measuring the sensation of color produced is known as a "colorimeter." Various forms of colorimeters are

[4] *Jour. Ind. Eng. Chem.*, 1921, p. 729.

known, the standard instruments being those which depend upon the colors of the spectrum itself, defining the color of an object in terms of its dominant hue, corresponding to a given position in the spectrum. Any color may then be defined in terms of the spectral position of its dominant hue and of the amount of white light which must be mixed with the spectral color to match the color in question.

This form of colorimeter is suitable primarily for use in the laboratory, but for use in the works more rugged and simple instruments have been designed, the latest being a subtractive instrument designed in the research laboratory of the Eastman Kodak Company which is based on the use of colored wedges, each wedge absorbing one-third of the color of the spectrum, so that the three wedges are yellow, blue-green, and magenta in color, the yellow wedge absorbing the blue light, the magenta, the green light, and the blue the red light. When these wedges are placed over each other in pairs, they will match any color provided that the intensity is adjusted at the same time by the use of a neutral gray wedge which is supplied as the fourth wedge of the instrument. The instrument is made with a number of attachments according to the purpose for which it is required, so that colored solutions, colored glasses, or colored pigments can all be measured by suitable attachments. A modified form of the instrument has been designed for use in measuring vegetable oils and especially for use with cottonseed oil.

EXPERIMENTS ON SULFIDE TONING.[5]

By E. R. Bullock and (in part) D. S. Mungillo.

(I) *The Effect of Modification of Ordinary Indirect Sulfide Toning.*—In the well-known method of sepia toning which consists in bleaching a black-and-white print in a bath of ferricyanide and bromide solution and redarkening it in a bath of sodium sulfide solution, a great many variations were made in the concentration, time of action, etc., of baths and also in the composition of the baths as far as this seemed possible without altering the chemical composition of the final (toned) image. The purpose of the experiments being to observe the variation with conditions of the color change which occurs on converting a silver image sub-

[5] Communication No. 116 from the Research Laboratory of the Eastman Kodak Company, published in *Br. Jour. Photo.*, July 29, 1921, p. 447.

stantially into one of silver sulfide, all such variations as the addition of a mercury salt to the bleach bath or of Schlippe's salt to the darkening bath were omitted.

Prints on Special Velvet Velox and Artura Carbon Black were prepared under conditions standardized for each paper and giving a supply of somewhat fully developed prints of good gradation in each case. The standard procedure adopted as normal for the toning process was substantially that given in recent issues of the *British Journal Photographic Almanac.*

A number of variations in the toning procedure which were found to have no influence on the final tone are enumerated in a separate table. A tone somewhat more purple than normal—hence usually an improvement—is obtained by the use of a bleach (such as permanganate-chloride) which converts silver to silver chloride, or by a brief immersion of the bleached print in a one per cent. sodium carbonate solution immediately prior to sulfiding, or (to a greater extent) by both. A tone which deviates—under certain conditions very greatly—from the normal in the opposite direction of yellow is obtained by the use of a plain ferricyanide, a ferricyanide-chloride, or a ferricyanide-iodide bleach, by immersing in an iodide solution prior to darkening, by adding iodide to the sulfide bath, by using a (yellow) polysulfide in place of ordinary (colorless) sodium sulfide, by using very dilute sodium sulfide solution as the darkening bath, or by having considerable hypo present in a somewhat (or very) dilute sulfide bath.

(II) *The Polysulfide Method of Direct Sulfide Toning.*—This method gives tones which are identical with those obtained with hypoalum, and which are considerably more purple therefore than those given by the standard method above. The preparation of a suitable polysulfide toning bath was described; and it was found that it is possible to accelerate the somewhat slow action of this bath, without affecting the tone obtained, by the addition to it of either potassium sulfocyanide or thiocarbamide.

The Effective Temperature of Certain Stars. NORDMANN AND LEMORVAN. (*Comptes Rendus,* July 11, 1921.)—The determination of the temperature is based on results obtained with the heterochrome photometer interpreted by a study of the distribution of intensity in the spectra of the stars. The absolute temperatures of 17 stars are given, ranging from 27,700° to a mere 3050°. The North Star is credited with 8200°. G. F. S.

The Principle of Projective Covariance. I. MAIZLISH. (*Phys. Rev.*, July, 1921.)—In terms of mathematics the principle means that the equations of this science are homogeneous in Minkowski variables, or that they are covariant with respect to four specified transformations. The author is able to derive some interesting conclusions from his premises. For instance, assuming that the wave-length for which the energy in a spectrum is a maximum to be a function of the absolute temperature alone he derives the known relation that the product of the wave-length and the temperature is a constant. Again, on the assumption that the mean kinetic energy of a perfect gas depends on the absolute temperature solely, he shows that the two are directly proportional. Even the laws of a vibrating string are readily derived from the principle. Such success in widely separated fields prompts the query, "How is it that such fine flour comes from the stones, when no suitable grain went into the hopper? May it not be that all the logical implications of the assumptions have not been clearly seen?"

It is claimed that the Principle of Similitude introduced by Tolman is only a special case of the general Principle of Covariance.

G. F. S.

The Value of the Surface Tension of Mercury when Surrounded by Different Gases. J. POPESCO. (*Comptes Rendus,* June 13, 1921.)—Stoeckle has shown that the surface tension of mercury decreases when the liquid rests in contact with any gas. The present investigator seeks to study the progression of this decrease. A large drop of mercury rests on a horizontal surface of polished steel. A simple relation exists between the surface tension and the vertical distance from the summit of the drop to its equatorial plane. It is from changes in this distance that changes in the surface tension are inferred. A bell jar of steel covered the drop which was observed by a cathetometer through a window. When there was a vacuum within the jar the surface tension was calculated to be 44.4 mg. per mm. Upon the admission of air the value rose to 51.13 at the beginning. As time passed it sank and after 24 hours it reached 42.55. Quite similar results were obtained with both ammonia and sulphurous anhydride. In both cases the initial values were higher than with a vacuum, a rapid decrease manifested itself during the first ten minutes and the final values attained were considerably less than in a vacuum, *viz.*—39.7 and 34.3, respectively.

When the surface tension was again measured in a vacuum after the mercury had been surrounded for a day by a gas, it was found to return to the original value. This indicates that some modification of the surface less permanent than a chemical change had taken place. The author suggests that the phenomenon is due to adsorption.

G. F. S.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE REACTION BETWEEN TUNGSTEN AND NAPHTHALENE AT LOW PRESSURES.

By Mary R. Andrews and Saul Dushman.

In the presence of an incandescent tungsten filament at a temperature above 1500° K, naphthalene ($C_{10}H_8$) is decomposed into carbon and hydrogen, the carbon being taken up by the tungsten. The rate of diffusion of the carbon into the tungsten is, however, extremely slow at 1500° K, and it is only at temperatures of 2300° and above that it becomes more rapid than the rate of decomposition of naphthalene at the pressures used. These pressures varied from .1 to 3.0 bars. Consequently most of the experiments on this reaction were carried out with tungsten filaments at temperatures ranging from 2300° to 2600° K.

By measuring the hydrogen evolved and also analyzing the filaments at different stages of carbonization it was found possible to determine the change in conductance with increase in carbon content. It was observed that the conductance at room temperature decreases linearly, with increase in carbon content, to a minimum value which is about 7 per cent. of that of the original tungsten. The carbon content at this point corresponds to the composition W_2C (3.16 per cent. C.). Further carbonization causes an *increase* in conductance to about 40 per cent. of that of tungsten when the carbon content has reached 6.1 per cent., corresponding to the formula WC. On further addition of carbon the conductance remains constant, indicating that no higher carbides are formed.

These experiments were carried out under such conditions that the pressure of naphthalene vapor in the bulb containing the filament was maintained constant at any desired pressure, while the hydrogen evolved was pumped out and collected in a separate reservoir. Thus the pressure of hydrogen in the neighborhood of the filament was kept negligibly low. It was therefore possible to measure ϵ, the ratio between the number of molecules decomposed and the number striking the filament per unit of time. It

* Communicated by the Director.

was observed that the value of this ratio decreases rapidly at the beginning of carbonization and then remains practically constant during the period of formation of W_2C. The actual value of ϵ in this stage varies with the pressure of naphthalene from about .02 to .06. At the point at which WC begins to form ϵ drops rapidly to .01 or less and continues to decrease as the carbon content increases. It is hoped to obtain an explanation of this phenomenon in the near future.

It has been found that for filaments containing less than 3.16 per cent. carbon the resistivity-temperature curves lie parallel to the curve for pure tungsten. That is, the difference between the resistivity of a carbonized filament and one of pure tungsten is approximately constant at all temperatures up to 2400° K. This is an extension of Delinger's rule which was enumerated to cover only impurities in metals, whereas in this case the added material forms a compound with the metal.

The two carbides both decompose at about 2700° K with volatilization of the carbon, so that the conductance increases finally to the same value as that of the original tungsten filament.

Preliminary measurements indicate that the melting points of W_2C and WC are about 3150° K and 3050° K, respectively. Determinations of the characteristics of carbonized tungsten filaments are in progress. It is also intended to investigate in the same manner the reaction between other hydrocarbons and tungsten.

SEPTEMBER 19, 1921.

Diffraction of X-rays by Liquids. A. DEBIERNE. (*Comptes Rendus,* July 18, 1921.)—In the last decade of last century when X-rays were new attempts were made to get evidence that they acted as light does. Reflection, refraction, diffraction were sought but in vain. Now it is known that a crystal acts in respect to X-rays as a diffraction grating toward ordinary light. Debye has found diffraction of the rays and the present paper reports the obtaining of this effect in a different way. A narrow beam of X-rays was sent through a layer of liquid sufficiently thick to absorb a good part of it. A photographic plate set perpendicular to the beam was placed in its path, but was shielded from the direct rays by a lead screen. After several hours of exposure the plate showed a central part free from trace of action by the rays, surrounded by an aureole. In some cases two diffraction rings clearly marked were obtained. Among the liquids used were mercury, methyl iodide and benzene.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION IX: THE NUTRITIVE VALUE OF THE PROTEINS FROM THE CHINESE AND GEORGIA VELVET BEANS.[1]

By A. J. Finks and Carl O. Johns.

[ABSTRACT.]

THE isolated proteins obtained by coagulation with heat from either the Chinese or Georgia velvet beans are adequate for the normal growth of albino rats. Chinese velvet bean protein prepared by dialysis, however, whether or not cystine was added, failed to promote normal growth. The bean meal, on the other hand, cooked or autoclaved and supplemented with either cystine or casein, resulted in nutritional failure, manifesting itself in lack of growth, regurgitation, diarrhœa, and, ultimately, death. These results strongly suggest the presence of a toxic factor.

THE CHEMICAL COMPOSITION OF PEANUT OIL.[2]

By George S. Jamieson, Walter F. Baughman, and Dirk H. Brauns.

[ABSTRACT.]

A STUDY was made of the composition of two samples of peanut oil one pressed from Spanish type peanuts grown in South Carolina, the other from Virginia type peanuts grown in Virginia. The samples had the following chemical characteristics.

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* Communicated by the Chief of the Bureau.

[1] Published in *Am. J. Physiol.*, 57 (1921) : 61.

[2] Published in *J. Am. Chem. Soc.*, 43 (1921) : 1372.

	From Spanish type peanuts	From Virginia type peanuts
Specific gravity, 25°/25°	0.9148	0.9136
Iodine number (Hanus)	90.1	94.8
Saponification value	188.2	187.8
Unsaponifiable matter (per cent.)	0.22	0.27
Acid value	0.12	0.03
Acetyl value	8.7	9.5
Reichert-Meissl number	0.27	0.21
Polenske number	0.12	0.29
Saturated acids per cent. (determined)	21.4[3]	17.4[4]
Unsaturated acids per cent. (determined)	73.4	77.7
Saturated acids per cent. (corrected)	20.6	16.4
Unsaturated acids per cent. (corrected)	74.6	78.7
Iodine number of unsaturated acids	121.8	118.2

The percentages of oleic and linolic acids were determined by analyzing the bromine addition derivatives of the unsaturated acids.

The saturated acids were converted into the methyl esters and fractionally distilled *in vacuo.* The constituent acids in the various fractions were separated by fractional crystallization from alcohol and identified by melting points and elementary analyses. The percentages were calculated from the mean molecular weights, determined by saponification.

The percentage composition of the saturated acids from the two oils is practically the same, but the oil from the Spanish type peanuts contains 20.6 per cent. of this saturated acid mixture, while the oil from the Virginia type contains only 16.4 per cent.

The composition of these two oils was found to be as follows:

		Oil from Spanish type peanuts per cent.	Oil from Virginia type peanuts per cent.
Glycerides of	Oleic acid	52.9	60.6
	Linolic acid	24.7	21.6
	Palmitic acid	8.2	6.3
	Stearic acid	6.2	4.9
	Arachidic acid	4.0	3.3
	Lignoceric acid	3.1	2.6
Unsaponifiable matter		0.2	0.3

Hypogæic acid was carefully tested for but could not be detected.

[3] Iodine number 4.8.

[4] Iodine number 7.1.

NOTES FROM THE U. S. BUREAU OF MINES.*

ROCK STRATA GASES IN MINES OF THE EAST TINTIC DISTRICT, UTAH.

By G. E. McElroy.

The development of certain mines in the East Tintic mining district, Utah, has been hindered considerably by the presence in the rock strata of heavy irrespirable gases which at times flood the lowest working places, as well as by abnormally high rock temperatures in the lower horizons. A study of these features was completed in the spring of this year.

The affected mines are on or near the crest of a large anticline composed of sedimentary rocks, almost entirely overlain by lava flows. The sedimentary rocks consist of a great thickness of quartzite separated from overlying limestones of considerable but varying thicknesses by a formation of pyritic shales, 300 to 500 feet thick, containing interbedded limestones.

As a rule, these heavy gases peculiar to this district, are not encountered in mining until the quartzite is pierced, although they occur in places in fissured zones in the overlying limestones. Abnormally high rock temperatures also appear to be limited to horizons close to the quartzite.

Calculation of samples to an air-free basis shows that the pure gas is primarily a mixture of carbon dioxide and nitrogen with the carbon dioxide in excess. The gas also contains some sulphur dioxide. The gas is 1.25 to 1.40 times as heavy as the adjacent air. The difference in weight causes the gas to drop to the lowest points, and form accumulations or pools. Diffusion with the mine air is relatively slow in quiet atmospheres but increases as the air motion is increased. The evidence gathered from the mines affected indicates that the heavy gases have resulted from oxidation of sulphides.

The necessity for good air motion at working places and the relatively slow rate of gas inflow, indicate that the best remedy is dilution of the gas inflow with large volumes of air by mechanical ventilation. Further details are given in a recent report issued by the bureau.

* Communicated by the Director.

PRESSURE-VOLUME DEVIATION OF METHANE, ETHANE, PROPANE AND CARBON DIOXIDE AT ELEVATED PRESSURES.

By G. A. Burrell and G. W. Jones.

As a part of the work which the Bureau of Mines carried out in 1916 and 1917 pertaining to the compressibility of natural gas, it became necessary to determine the pressure-volume relations of several of the paraffin hydrocarbons of which natural gas is composed.

Results of the work on natural gas were published in *Technical Papers 131* and *158*, and curves were given of pressure-volume deviations of the gases, methane, ethane, propane, and carbon dioxide at high pressures. The original experimental data on these gases, however, were not published.

In view of many inquiries which the Bureau has received with reference to the original data on these gases, and the importance of the pressure-volume relations from which it is possible to calculate the deviation of any natural gas whose composition is known, the original data as determined by Burrell and Robertson have been issued in mimeograph form.

The apparatus and method of procedure used for determining the pressure-volume relation is described in *Technical Papers 131* and *158*. The methods used in preparing the gases for pressure-volume deviations at elevated pressures were as follows: Methane, fractional distillation of natural gas at low temperatures and pressures; ethane, electrolysis of sodium acetate; propane, action of propyl iodide on a zinc-copper couple; carbon dioxide, action of sulphuric acid on a solution of potassium bicarbonate. In preparing these gases, extreme care was taken to rid them of all impurities. In every case, the final method of purification was fractional distillation at low temperatures and pressures.

FOURTH SEMI-ANNUAL MOTOR GASOLINE SURVEY.

By N. A. C. Smith.

The Bureau of Mines motor gasoline surveys have been conducted in January and July, during 1920 and 1921. The Bureau has obtained and analyzed samples of gasoline representative of that marketed in the larger cities. These surveys have indicated that the gasoline on the market during the winter months is more volatile than that sold during the summer months. Naturally,

the motorist desires a more volatile gasoline in the cold winter months, as it affords greater ease in starting.

The fourth semi-annual motor gasoline survey, conducted during the month of July, shows an interesting relation between the market price and the quality of motor gasoline. This is particularly evident if figures obtained to-day are compared with those of a year ago. At the time the Bureau of Mines conducted its summer survey of motor gasoline last year, the average tank wagon price of gasoline was 28.2 cents per gallon. This year it was 21.2 cents, a drop of practically 25 per cent.

The nine cities in which samples of gasoline were collected this summer and the tank prices are as follows:

MOTOR GASOLINE TANK WAGON PRICES (IN CENTS PER GALLON).

City	July, 1920	July, 1921	Difference
New York, N. Y.	30.0	24.0	6.0
Washington, D. C.	28.5	22.0	6.5
Pittsburgh, Pa.	29.7	22.0	7.7
Chicago, Ill.	26.0	18.0	8.0
New Orleans, La.	28.0	17.5	10.5
St. Louis, Mo.	25.7	17.4	8.3
Denver, Colo.	31.0	22.0	9.0
Salt Lake City, Utah.	31.5	25.0	6.5
San Francisco, Calif.	23.5	23.0	0.5
Average	28.2	21.2	7.0

In spite of this drop in price, the quality of gasoline to-day is much better than it was last summer, in fact, the average gasoline to-day is almost identical in quality with the average gasoline sold last winter. Tabulated details are given in a recent publication of the Bureau.

Hydro-Electric Power. (*Electrician*, Sept. 2, 1921.)—In Reykjavik, Iceland, there has recently been opened an electric power plant with two dynamos of 1000 and 500 horsepower respectively. There are two water-power companies in the island, the Danish-Islandic and the Norwegian-Islandic, which control streams capable of furnishing millions of horsepower. The local problem is the finding of a market for the immense available power.

In New South Wales favorable legislation has stimulated hydro-

electric development. Plans have been prepared for the Barren Jack and the Nymboida installations while a considerable number of municipal projects are under way. The question of the utilization of the water-power resourses of the state is pressing. The government has had to refuse an application for 5000 H. P. for the manufacturing of aluminium and there are frequent inquiries for power from persons connected with electrothermic and electrolytic manufacturing.

The power station at Trollhattan in Sweden has 13 turbines with an aggregate of 166,000 H. P. At Mottala in the same country, work was begun on the station in October, 1918, and will be completed in April, 1922. Eventually there will be five turbines, each of 6000 H. P., direct coupled to dynamos developing three-phase current, 50 cycles, at 6000 volts. This will be transformed to 70,000 volts for long distance transmission.

Since Switzerland has neither iron nor coal her industrial success is remarkable. In large measure this is due to the development of the water-power of the country, which indeed was well under way a generation ago. When the war intervened to prevent the customary importation of coal from adjacent countries a fresh impetus was given to such development, with the result that there are now no less than 6870 power stations in this small country, of which 178 have an output of more than 500 H. P. The annual energy furnished by these stations equals that obtainable from 4,000,000 tons of coal.

G. F. S.

Magnetic Susceptibility of Nickel and Cobalt Chloride Solutions. LAURA BRANT. (*Phys. Rev.*, June, 1921.)—A decade ago Pierre Weiss, now of the University of Strasbourg, advanced the suggestion that the magnetic moments of molecules of different elements were whole multiples of an elementary moment to which he applied the name "magneton." The evidence for the existence of such a quantum of magnetic moment has been far from overwhelming with the result that the magneton is still *sub judice*.

The present investigations led to the calculation of the number of magnetons per molecule of nickel and also of cobalt. For the former the number came out 16 in accordance with the previous results of Weiss and Mlle. Bruins. Though the solutions used differed greatly in concentration the calculated number of magnetons per molecule had no greater range than from 15.98 to 16.04.

For cobalt the number came out 24.498 with a range from 24.47 to 24.51. This is, of course, not a whole number. "The number for cobalt presents again the half-magneton already found in the case of other solutions: It would agree with Weiss's theory if the gram-magneton were assigned half the value."

G. F. S.

He devised several improvements in injectors and steam-jet apparatus and was also the inventor of a two-cylinder cross-compound and a tandem-compound locomotive.

Mr. Colvin became a member of The Franklin Institute on September 3, 1884 and in 1892 was elected a member of its Committee on Science and the Arts, serving continuously since that time. He took an active part in the work of this Committee and was also intensely interested in the success of all the Institute's undertakings.

Mr. Wharton Barker, Port Royal Avenue, Roxboro, Philadelphia, Pennsylvania.

Mr. James G. Davis, The United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

Mr. W. W. Frazier, Drexel Building, Philadelphia, Pennsylvania.

Mr. Thomas W. Sparks, 4100 Walnut Street, Philadelphia, Pennsylvania.

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This investigation was undertaken by the Committee at the Langley Memorial Aeronautical Laboratory for the purpose of developing instruments that would record the forces and positions of all three controls, and to obtain data on the behavior of an airplane in turns. All the work was done on a standard rigged JN4H (airplane No. 2 of N.A.C.A., Report No. 70). It was found that the airplane was longitudinally unstable and nose heavy; that it was laterally unstable, probably due to too little dihedral; and that it was directionally unstable, due to insufficient fin area, this last being very serious, for in case of a loss of rudder control the airplane immediately whips into a spin from which there is no way of getting it out. On the other hand, it was found possible to fly quite satisfactorily with the rudder locked, and safely, though not so well, with the ailerons locked. The value of Y_v was obtained in free flight, and when the effect of the propeller was subtracted, the agreement with the model test was excellent, but with the propeller revolving at 1350 the value of Y_v was nearly doubled. The value of L_v and N_v were little affected by the slipstream, but their values do not agree with the model test.

Report No. 114, Some New Aerodynamical Relations by Max M. Munk. 13 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This report contains three new relations extending the modern theory of aeronautics, intended to be applied in some later papers. They deal with phenomena in a frictionless fluid.

The first part contains a relation between the power absorbed by an aerofoil and the power absorbed by a propeller. In the second part the exactness of the ordinary formula for the induced drag of an aerofoil is examined and the error is determined.

In the third part the author shows that for the calculation of the air forces on bodies of considerable volume the imaginary sources and sinks equivalent to the flow around the body can be used in the same way as vortices are used for the calculation of lift and induced drag of wings.

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THE SCIENCE OF ELECTRIC WELDING.*

BY

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INTRODUCTION.

The art of welding iron is undoubtedly one of the first acquired by man in his use of this metal, for it was only by its practice that the iron, produced by the early low temperature reduction processes, could have been associated into a mass of useful proportions. This art reached its zenith during the period of the fifteenth to the eighteenth centuries as expressed in the magnificent screens and grills at Florence and Verona, and in England.

Up until the nineteenth century the blacksmith's hammer and anvil were the only known tools for welding, but the progress of time has substituted a new method of joining metals by fusion, first, by the use of compressed gases and latterly by the use of electrical energy.

The title of this paper represents, possibly, more of a hope than an accomplished fact. Much of the "art" still clings to even the most modern practices in electric arc welding. However, our present day industries require the closely controlled and definitely reproducible processes of science and the progress of recent years has indeed gone far toward placing this art of welding on a scientific basis. The work of the Welding Committee of The National Research Council has done much toward the accomplishment of this end.

* Presented at a meeting of the Electrical Section held Thursday, March 24, 1921.

HISTORY.

The use of electric energy for joining metals had its inception along about 1874, when Werderman proposed to use the heat of a carbon arc deflected to the point of use by a jet of air. This idea was later improved upon by Zerener, who deflected the arc by means of a magnetic field. Both of these processes required considerable time and skill for their application, and neither ever attained any commercial importance. Credit for the first arc welding, as it is now applied, is generally attributed to de Meritens, who in 1881 used an electric arc from a carbon

FIG. 1.

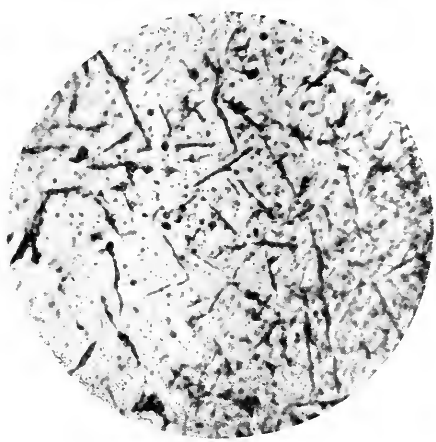
Oxide and nitride in deposited metal. ×75.

electrode to weld the lead of storage battery plates. A few years later this process was extended to welding other metals by Benardos, of St. Petersburg. A further development is due to Slavianoff, who substituted a metal electrode for the carbon and used the molten metal from this electrode for filling blow holes and cracks in defective castings. For many years the application of these processes languished for want of proper electrical machinery for generating and applying the energy needed, and the progress made goes hand in hand with the perfection of electrical equipment, which has been rapid during the last ten years.

About the same time as these beginnings were being made in arc welding, Elihu Thompson, in 1877, experimenting in the Laboratory of The Franklin Institute here at Philadelphia, conceived

the idea of joining metals by the resistance method, and in 1886 made public his first apparatus. This was designed to hold together two pieces to be welded, while passing a heavy current through them until the abutting edges reached fusion and joined under the pressure applied. Modifications of this butt welding quickly followed in spot, ridge and seam welding. The latest development along this line is percussion welding, which differs only in the character of the energy applied. In this case a sudden rush of stored up current from a condenser or magnetic field is applied and at the same instant union is obtained by pressure on the parts.

FIG. 2.



Same as Fig. 1—annealed. ×75.

By this method a greater concentration of energy is obtained than in spot or butt welding, there is less "flash" or extruded metal, different metals are readily welded together and due to the concentration and short duration of the heating a minimum amount of metal is affected by the heat. It is estimated that the time of fusion and union is about .0095 sec. At least three-fourths of the power is saved as compared with butt welding. Unusual welds may be made, such as welding small rods to heavy blocks without previous treatment of the surfaces. As only a very small area is heated it may be safely used when loss of temper would be injurious. Unlike metals are readily welded and the quality of the weld, after proper adjustment, is independent of the skill of the operator.

The most recent researches in spot welding as a substitute for riveting have been along the line of developing machines for spot welding heavy sections. These have been built for welding through 1″ thicknesses of plate. Such a machine has a current capacity of 100,000 ampères and is capable of exerting a pressure of 75,000 pounds. Duplex machines having a six-foot span, and designed to weld two spots at a time have been used to a limited extent to replace riveting machines. It is estimated that there is a saving of 25 to 50 per cent. in time by using spot welding as compared with riveting, if the time of punching holes, laying out, lining up, etc., is counted.

FIG. 3.

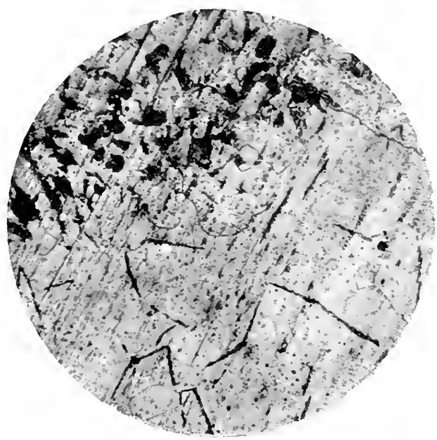
Deposited metal. ×75.

Spot welding machines, particularly when heavy currents are required, are heavy and for use where portability is necessary, require crane service. The single-phase current used is also a disadvantage, for power companies object to the unbalancing of their systems. When small equipments are used this disturbance is not serious, or if a number of welders are used they may be distributed among the various phases of a polyphase system. The actual cost of power per weld is very small, and the saving over riveting, under constant service conditions, would easily pay the investment charges on a motor-generator equipment to correct defects in loading electrical systems.

Resistance welding, in its different forms, quickly found many applications, its chief development being in the perfection of automatic machines for handling large production of like pieces. Hoops, tires, chain links, wire fence, lathe tools, kitchen utensils, iron ladders and gratings, and a large variety of other products are now welded in these automatic and semi-automatic machines.

The recent increase in the application of electric welding, particularly of arc welding, has given rise to many questions having to do with the quality of the product and its trustworthiness under severe service conditions. During the war the National Research Council and Emergency Fleet Corporation appointed a welding

FIG. 4.



Annealed weld, showing boundary between plate and weld. ×75.

committee to study the problem in connection with the welding of ship plates. This committee did much to stimulate research on electrodes, current strengths, the nature of the arc, inspection methods and the instruction of welders.

CARBON ELECTRODE ARC WELDING.

This, the oldest of the arc processes, is still being used to quite a large extent. Although the use of the metallic electrode has received a large share of attention and publicity in recent years, this process still has its distinct field of usefulness which should not be overlooked. It is used in four ways: By using the heat of the arc to fuse together abutting edges of metal sheets or plates; by fusing

a metal filling rod into the space to be welded; by combining the metallic and the carbon arc, and for cutting.

The electrodes are of carbon or graphite, according to preference of the welder. Some users claim that a lower rate of consumption and a softer weld is obtained from the latter. The size is determined entirely by the current to be used and varies from ¼″ tapered to ⅛″ for currents of 50–150 ampères on light work, to 1½″ tapered to ⅛″ for 800–1000 ampères for use on very heavy melting and cutting work. The electrodes are always tapered and this original taper is maintained by the electrode. This taper makes the arc more stable and easily controlled.

FIG. 5.

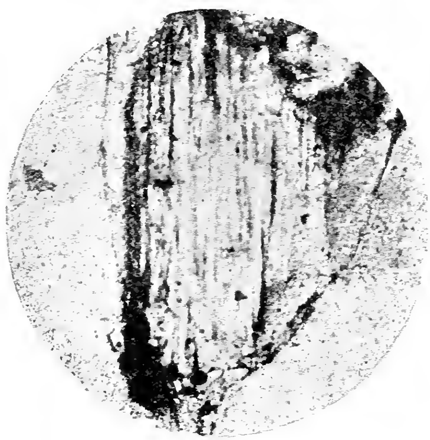
Boundary between plate and weld. Note coarsened grain of plate stock. ×75.

As the positive terminal of an arc attains a much higher temperature than the negative the metal to be welded is usually made positive. This results in a minimum heating of the electrode and a more stable arc. Even when made the negative pole, the carbon heats considerably, causing much burning and vaporization of the carbon. If carelessly handled much of this carbon finds its way into the fused metal, hardening it to a great degree. If the arc length is properly maintained much of this carbon vapor is burned in the arc stream. The arc length, although flexible, should seldom be less than ½″ and except for very high currents should not exceed 1″, to obtain a soft weld with a minimum of oxidation.

Without the use of filling material, the process is used for

welding flanged edges of sheet steel and non-ferrous metals, and for cutting. With a filling rod it finds its chief application in the welding of cast iron and cast steel, filling in defective spots and building up worn surfaces. The combined carbon and metal arc processes are used where careful preheating is necessary as in cast iron. The carbon arc is used to preheat the surface around the point to be welded and the metal arc used for the actual welding operation.

FIG. 6.



Slag inclusion in weld, covered electrode used.

On the whole, the carbon arc process requires less skill than the metallic arc and, for welding light plates and sheets, filling in defective castings and cutting off risers for castings, it is cheaper than any other process.

METALLIC ARC PROCESS.

A rapid advance in the knowledge of metallic arc welding has taken place in the last decade. A great impetus to its study came from the war demand for ships. It then became important to know as quickly as possible what electrodes to use, what current density was best, how to prepare the edges for welding, how much the weld would stand, and how reliable was one weld as compared with another made under like conditions.

The making of a good weld is essentially a metallurgical problem. The study of electrode materials, the deposited metal and the

mechanism of transfer from the one to the other through the arc stream have been of particular interest to the present writer, and the results of this study will be discussed in some detail.

METALLOGRAPHY OF WELDS.

The physical properties of a weld or of any steel casting will depend upon the grain, solidity and chemical composition. Unfortunately the conditions under which a weld must be made are such as to effect these factors unfavorably. The grain is usually coarse, due to the method of cooling, but a skilful welder can produce a fine grained structure by depositing the metal rapidly in comparatively thin layers. In this way the plate is not heated up

FIG. 7.

Plate stock—mild steel. ×75.

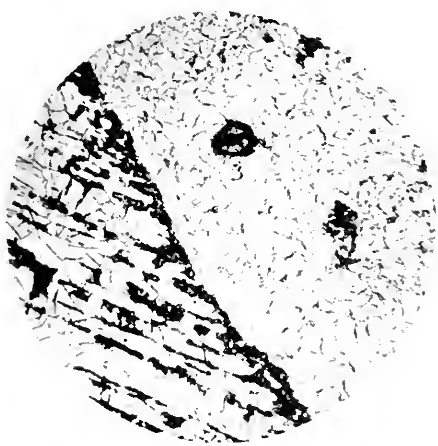
sufficiently to slow down the cooling of the deposited metal, and each successive layer serves as a partial heat treatment to those underneath.

Gas holes are found to a greater or less degree in all welds. They may come from the use of an electrode that is too high in carbon and other gas forming impurities, but most frequently are caused by the highly oxygenous weld metal coming in contact with the carbon in the fused plate metal. They are minimized by using as short an arc as possible, depositing the metal rapidly and keeping the impurities low in the plate metal. Occluded gases in the electrode have little effect in this respect, but have a very bad effect on the solidity of the weld if present in the plate metal.

Slag inclusions (Fig. 6) are a common source of weakness in welds and are due almost entirely to poor workmanship. One layer is put over another without proper cleaning or the pool is not kept molten long enough to float off the slag formed from the oxidation of the electrode. Particular care must be taken when working with coated or filled electrodes. Wrought iron electrodes can also give trouble in this respect.

The two most important elements present in the weld material are oxygen and nitrogen (Figs. 1–8). Both may be present in amounts sufficient to be harmful to the ductility of the deposited metal. Some oxygen is held in solution in the iron, but usually it may

FIG. 8.



Annealed plate and weld boundary. Note penetration of N into plate. ×75.

be seen in small patches or spots. Welds are never free from it, but usually there is not sufficient present to account for the usual lack of ductility. It is probably also present in the form of a thin film around the grains, but this is not visible under the microscope. Until a few years ago the presence of nitrogen was not given serious consideration. A thorough study [1, 2, 3, 4] of certain characteristic structure always found in welds proved, however, that

[1] Structure of Fusion Welds. S. W. Miller, *A. I. M. E.*, **58**, 700 (1918).

[2] The Metallurgy of the Arc Weld. W. E. Ruder, *G. E. Rev.*, **21**, 941–6, (1918).

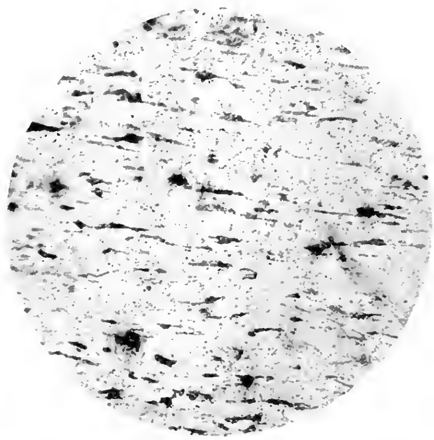
[3] Nitrogen in Steel. Comstock and Ruder, *Met. Chem. Eng.*, **22**, 399 (1920).

[4] Nitrogen and Erosion in Guns. Wheeler-Discussion (Ruder), *A. I. M. M. E.*, Feb. (1921).

this element was not only present in amounts up to .15 per cent.–.2 per cent., but was a most important factor in causing "cold-shortness." The effect of heat treatment was studied and a new method of etching was developed [4] which distinguished between the nitrogen bearing areas and other metallographic constituents.

It may occur as needles, eutectoid patches or surrounding the grains as a film of varying thickness (Figs. 11–22, inc.). As little as .06 per cent. N will reduce the elongation in a .2 per cent. C. steel from 20 per cent. to 5 per cent. Under ordinary conditions of fusion N has little effect on iron, but under the conditions of the electric arc the gas molecule is broken up and the N atom readily

FIG. 9.



"Pure" iron welding rod. ×100. This rod has excellent welding properties.

combines with the molten iron particles and iron vapors.

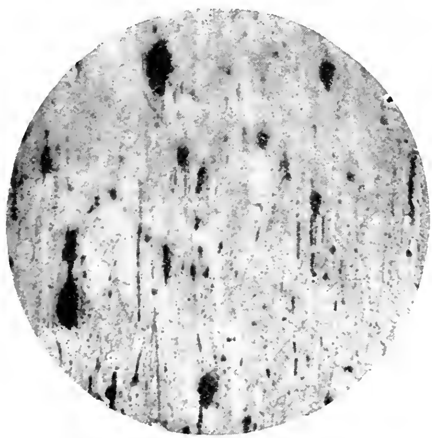
Both the oxygen and nitrogen content of the fused metal are probably kept at a minimum by using a short arc in depositing the metal and by maintaining a current value which does not exceed that necessary to fuse and transfer the metal. Excessive current will increase the oxygen and nitrogen content to a point where the deposited metal will be excessively brittle.

S. W. Miller [5] has shown that the path of rupture in steel fusion welds does not bear any relation to the nitride needles, and concludes from this that their presence is not a direct cause of brit-

[5] Miller, Path of Rupture in Steel Fusion Welds, *Bull. A. I. M. E.*, No. 146, Feb., 1919, p. 311.

tleness in welds. The point that should not be overlooked in this connection, however, is that nitrogen in steel acts like carbon in this respect, that it is the *N* remaining in solution in the ferrite that causes the brittleness. The *N*-needles, as I have shown,[6] are produced by slow cooling, and their presence indicates that nitrogen is present, but does not mean that all the nitrogen has been released from solution in the ferrite, nor does their absence indicate the total absence of nitrogen (Figs. 21 and 22). A rapidly cooled weld may contain as much at .1 per cent. *N*, and still appear under the microscope as pure ferrite (Fig. 21).

FIG. 10.



Steel welding rod. ×100. This rod contains much gas. Requires dipping for good results.

The needles present merely represent an equilibrium between the dissolved nitride and that precipitated from solution under the particular conditions of heating and cooling. Interesting data confirming this are given by Owens, Ramage and Watts, in a paper recently presented before the American Welding Society, in which they show that the ductility of a weld is greatly increased by slow cooling from 1200° F. Their micrographs also show the same changes in structure due to heat treatment as those of nitrogenized iron.

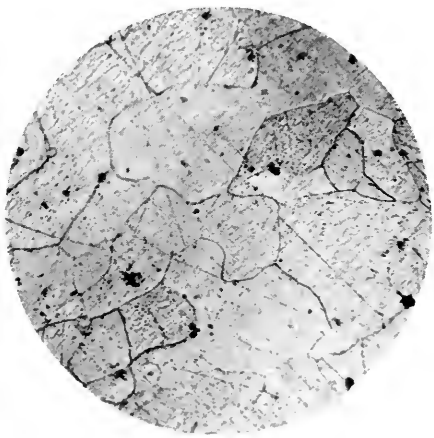
METAL TRANSFER.

The metal from the electrode is transferred to the weld partially by vaporization and condensation, partially by expulsion of

[6] Comstock and Ruder, *Chem. Met. Eng.*, 22, 399 (1920).

the molten metal due to the explosion or rapid expansion of gaseous products formed by oxidation in the electrode tip, and partially by surface tension and gravity. Although in normal welding practice the largest amount of metal is transferred by the last method, the expulsion of particles of molten metal by gases plays an important rôle. If gas-forming impurities are not present in some degree, the metal will transfer, but the deposit so formed will not "bite in." The metal drops transfer by the molecular attractive forces, but act more like molten solder. Overhead welding under these conditions is almost impossible because the drops formed become so large that the force of gravity overcomes that

FIG. 11.



Same as Fig. 9—annealed. ×100. Good welding properties.

of surface tension, and the metal drips down the side of the electrode.

The action is somewhat improved, by reversing the polarity from negative to positive, due to the more rapid heating and greater vaporization of the electrode. The sudden expansion of the metal vapors, in this case, supply some projecting force, but not enough to give a satisfactory penetration, which should be at least $^1/_{16}''$ as determined by the depth of the arc crater. Ordinary mild steel and commercial ingot iron electrodes usually contain enough carbon and slag to give the necessary "kick," and extreme care must be taken to have a very pure wire if the effect of the absence of impurities is to be noted. Failure to note this has led some

investigators to reject, as irrelevant, the gas propulsion theory originally proposed by Hudson; the assumption having been made that the wire used was "pure" because it was so labelled by the manufacturer.

ELECTRODES.

These may be divided into two general classes—bare and flux covered. For most work, in either case, a mild steel wire, varying in thickness from $^3/_{32}''$ to $^3/_{16}''$, is used. The diameter depends on the size of the weld to be made, and therefore upon the amount of current to be carried. The smaller diameter bare wire ($^3/_{32}''$) is used for currents of from 50 to 75 ampères and the larger ($^3/_{16}''$)

FIG. 12.

Same as Fig. 9—purified. ×100. Will not weld under any treatment.

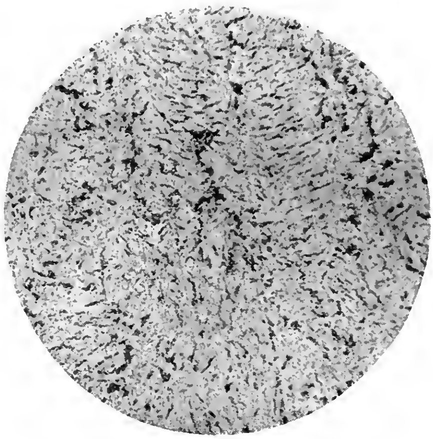
for currents of from 185 to 275 ampères. For covered electrodes these values should be cut to about one-half. The composition is approximately C. .18 Si. .08 Mn. .50 S. .05 P. .05 (max. value). In passing through the arc most of these impurities are oxidized and do not appear except in much smaller percentages in the deposited metal, but others, oxide and nitride, do appear and are kept at a minimum by the maintenance of a short arc (⅛").

If electrodes are pickled, excessively rusted or contain too much carbon, sputtering results due to the generation of gases from the carbon and atmospheric oxygen or the liberation of occluded gases. This condition may usually be remedied by dipping the electrodes in lime or various other coating materials which serve to steady

the arc. Some manufacturers produce wires which are quite true to composition, but vary considerably in operation. In several cases this has been traced to excessive gas content in the wire. Another wire manufacturer produces a wire advertized as being of high purity. This wire works well all the time, but its good operation depends upon its slag content, for if it is further purified by removing this slag it makes a very poor welding wire indeed.

Many attempts at improving the ductility of the weld by adding various deoxidizing or denitrogenizing elements to the electrode have been made, but none has been entirely successful, due to the fact that any such element (Al, Ti, V, B. etc.), is rapidly attacked

Fig. 13.



Weld made in nitrogen gas. ×75.

and lost during its passage through the arc stream. To be most successful such an element should be added to the plate material or the molten pool with fusion maintained for a sufficient time to float off the slag products. This is always important, but particularly so when slag covered electrodes are used, to insure proper puddling of the fluid area in order to release entrapped slag and to give it an opportunity to combine with the iron oxide present.

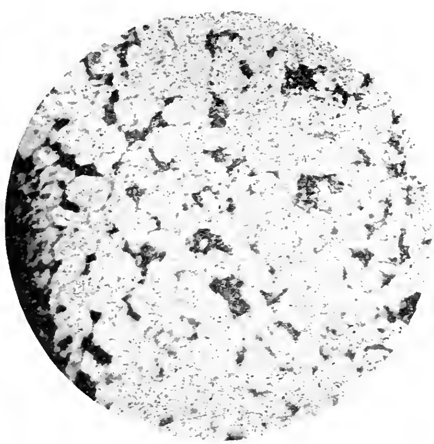
RELIABILITY OF THE WELDED JOINT.

There is now a mass of data to show that a welded joint, provided it was conscientiously made by one skilled in the art, is a good engineering risk. Arc welded butt joints can be counted on

to have at least 90 per cent. of the strength of the plate, and spot welded joints are stronger than riveted joints. Although there is still considerable room for improvement in ductility, actual experience with welded joints has shown this lack of ductility to be of less importance than it was first feared it might be, particularly in welding soft steel.

These statements presuppose to fact that the weld has been well made. A proper inspection of welds is imperative, yet it would be difficult to describe what a good weld should look like. Such knowledge is only to be obtained by experience resulting from destructive tests of a large number of welds. For this reason

FIG. 14.



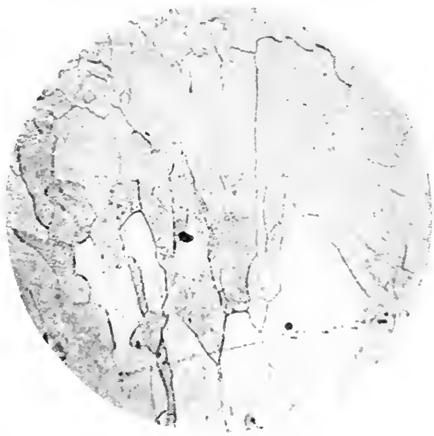
Weld made in CO_2 gas, no nitride present. ×75.

emphasis must be placed upon the thorough training of the welder which will allow him to test his product by bending and deep etching until he can make satisfactory welds every time.

The bending test, made by clamping the welded piece at the point of the weld and hammering one end until the weld opens up, will disclose defects due to improper joining with the base metal and excessive slag inclusions. The deep etching test made by cutting a section through the weld, polishing and etching in hot 25–50 per cent. hydrochloric or nitric acid will disclose inclusions and porosity otherwise invisible (Figs. 23–24). This etching will also disclose the structural change which has taken place in the base

metal. This change is very important, particularly when medium or high carbon steels are welded. It is caused by a solution of some carbon, present normally as pearlite, and by a coarsening

FIG. 15.



Weld made in hydrogen. No oxide or nitride present. ×75.

FIG. 16.

Pure iron—nitrogenized by heating in ammonia. ×75.

of the grain, both of which tend to embrittle the metal. Such conditions are corrected by annealing after welding, and for this reason steels of high carbon (over .3 per cent.) or alloy content

are satisfactorily welded only if preheated and subsequently annealed. Such annealing will also relieve internal stresses in hard materials, castings, etc.

FIG. 17.

Same as Fig. 16—quenched in water from 700°C. ×50.

FIG. 18.

Same as Fig. 17—reannealed.

Magnetic, resistance, and X-ray methods have been suggested as non-destructive tests for welds, but none of these have yet been perfected to a point where they can be easily applied to commercial products.

ELECTRICAL CHARACTERISTICS AND EQUIPMENT.

During the past few years the technical and engineering press has been flooded with articles dealing with the various applications

FIG. 19.

Same as Fig. 16—quenched from 800°C. in water. ×50.

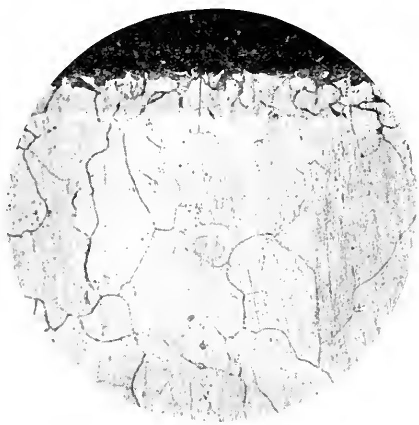
FIG. 20.

Same as Fig. 19—reannealed. ×50.

of welding. The selling price of arc welding apparatus exclusive of accessories and supplies, sold in the U. S. during 1920, is estimated at approximately $2,000,000. Accessories and supplies, such as electrode material, etc., will probably amount to $2,500,000.

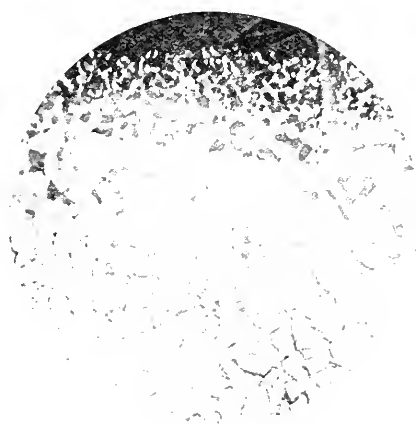
The apparatus generally consists of standard material such as motor generators, switch boards, motor starters, etc., with more or less minor changes to make the equipment suitable for arc welding

FIG. 21.



Same as Fig. 16—quenched in water from 950° C.

FIG. 22.



Same as Fig. 20—reannealed. ×50.

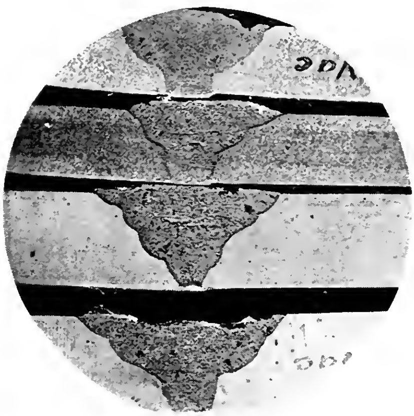
service. The demand for this equipment appears to be more settled than that for other electrical equipment, for when business conditions are such that ordinary purchases of equipment are deferred, arc welding becomes of greater importance for salvaging

and repairing used or discarded parts. This has a tendency to keep up the sales of arc welding apparatus to somewhere near the normal level.

FIG. 23.

Deep etched welds. Note improper joining at base of V in 2.

FIG. 24.



Deep etched welds. ×½.

ALTERNATING VERSUS DIRECT-CURRENT WELDING.

Direct-current welding is in most general use in this country, and in its simplest form, requires only a rheostat of sufficient capacity and a D. C. source of current supply. Unfortunately,

however, this is seldom available, so that a motor generator set is required. The generator is especially designed to have the proper characteristics for arc welding service. This generator is driven by a motor of standard construction to meet the need of the available supply circuit, and the only concern of the central station is that the circuit is of sufficient capacity to drive the load, as the equipment has the commercial power factor of an ordinary induction motor load. The inertia of the revolving parts tends to cushion somewhat the sudden load changes as the arc is struck or broken.

There is still some difference of opinion as to what are the proper characteristics for the generator supplying energy for arc welding. It appears, however, that the ideal condition for obtaining a good weld on a given piece of work is obtained when current and voltage at the arc are constant. With a manually controlled arc this condition is impossible of entire realization. To make conditions as near the ideal as possible a constant energy set has been developed, the principal advantage of which lies in the fact that it facilitates the maintenance of a short arc and makes it difficult to keep a long arc. As the rate of consumption of electrode material depends upon the current and is independent of the voltage, a shortening of the arc causes more rapid electrode consumption with a consequent return of the arc length to normal.

The load factor of a single operator arc welding equipment varies from 5 per cent. to 70 per cent., depending upon the kind of work done and the method of handling it. The capacity factor is probably half of this figure, since only a small portion of the work requires the full output of the welding equipment. In the case of a large multi-operator, constant potential equipment, the capacity factor may be increased considerably.

There has always been a certain amount of conflict in reports of tests of welds made with an A. C. or a D. C. welding system. If the comparison is made without prejudice I believe that each system has its distinct place in industry. As compared with direct-current system, alternating-current systems have the advantage of low first cost of equipment, and for the small repair shop this is of some importance. Against this we have the disadvantage of low-power factor (20–40 per cent.), single-phase operation, and greater difficulty in arc maintenance. These objections are very real and have led many engineers to decide against the use of A. C. There

are many small construction and repair shops, however, where an arc welding set would be of great service, but where the installation of a D. C. equipment is out of the question due to first cost. In such cases A. C. welding could be used to advantage, for the small load would not greatly unbalance the system or the low-power factor greatly disturb the central station.

Carefully made experiments have shown that there is little to choose between in the quality of the welds produced by experienced operators, with either system. A. C. welds have frequently been condemned because the job was not done with sufficient care, and the arc was not maintained with sufficient skill. If this is done, there does not appear to be any essential difference in the character of the metal deposited.

Some claim has been made for A. C. welding systems that they operate from polyphase circuits, but this does not mean that the load is balanced. A single-phase load cannot be transformed into a balanced three-phase load by static transformers alone. Such a condition creates as much or more disturbance as does an unbalanced current load, and some electricity supply companies have prohibited the use of A. C. arc welders on their lines.

AUTOMATIC ARC WELDING.

Just as the increased use of resistance welding quickly brought into use automatic devices for increasing speed and reliability of product, so the automatic electric arc welding machine promises to find an important place in this form of welding. This machine will weld at a speed of from two to six times the rate possible by skilled operators welding by hand, due to the stability of welding conditions and the elimination of the necessity for changing electrodes.

The characteristics of practically all electric welding circuits are such that the current and voltage are interrelated, an increase in one causing a corresponding decrease in the other. The automatic arc welding machine utilizes the arc voltage as a basis for regulating the equipment. A shunt wound motor having the armature connected across the welding arc will vary in speed as the arc lengthens or shortens, due to the variation of the arc voltage. Now, if this motor is connected through suitable gearing to the electrode wire, the wire will be fed into the arc at a rate depending upon the arc voltage it is desired to maintain. A vibratory relay is also connected across the circuit in such a way that the relay

contacts open when the voltage increases. This cuts resistance into the field circuit of the feed motor, still further tending to increase the feeding speed. As a result, the wire is continuously fed into the arc at an almost constant rate, and the electrical conditions, as indicated on the switchboard instruments, are very steady.

As is the case with other automatic machines, the principal field for the automatic arc welder is one where a considerable amount of welding is required, calling for a continuous repetition of duplicate welds, building up pulleys, shafts or worn bearings. Unland [7] gives an example of the saving in cost in welding crane wheel flanges. These were repaired at a cost of $4 by automatic welding and $9 by hand welding.

CONCLUSION.

Of the application of electric welding in its various forms to our present day industry volumes have already been written. In a multitude of applications it has proven not only its economy but its entire reliability. Although the quality of the weld is still largely dependent upon the skill of the welder, through the application of scientific knowledge in the perfection of electrical equipment, the selection of materials and the training of welders, the title of Science has at least a foundation in fact.

BIBLIOGRAPHY.

A very complete bibliography of books and articles published on welding has been published by Jacob G. E. Rev. **21** (652–658) 1918. This includes all publications between 1914–1918. For earlier works, W. B. Gamble, of the New York Public Library, published a bibliography covering the period 1786–1913. This was published by that Library in 1913.

Sodium Carbonate, Hydrated. (*U. S. Geological Survey Press Bulletin No. 478*, October, 1921.)—Sal soda, hydrated sodium carbonate, washing soda, or crystal carbonate, having the chemical formula $Na_2CO_3.10H_2O$, is made from soda ash by dissolving it in water and allowing the solution to crystallize below 32° C. It is used in softening water and for many other purposes for which soda ash is used where purity is an essential requirement. It is also used in cleansing compounds or alone as washing soda.

According to the Survey, the production of sal soda in the United States in 1920 was 62,857 short tons, valued at $128,937.

[7] *American Machinist,* Aug. 26, p. 405 (1920).

Reduction by Zinc and Cadmium.—Zinc has been long used for reducing ferric salts in the analysis of iron compounds. TREADWELL (*Helv. Chim. Act.*, 1921, iv, 551) presents the results of an elaborate investigation made by Lüthy and Rheiner into the common methods and a comparison of the zinc method with that of cadmium. In the original process the zinc was used in fragments, but Carnegie, in 1888, introduced the use of the powdered metal by which much more rapid action is produced. Many trials and improvements were introduced, by which the reduction was greatly expedited without material sacrifice of accuracy. Treadwell's paper gives the results of many experiments, the conclusion being that finely divided cadmium is adapted to the determination of iron, titanium and mixtures of the two, as well as for molybdenum, vanadium and uranium. The zinc reduction was found to be satisfactory for iron.

H. L.

Comparison of Cost of Electric and Fuel Furnaces.—Patch, in a communication to the fortieth meeting of the American Electrochemical Society, held recently, has made a careful comparison on this question, and expresses the opinion that the costs are substantially the same if proper attention is given to the details of operation. Contrary to what might be expected, *a priori*, the solution of gases in the molten metal is about the same in both systems. The claims of makers of electric furnaces for marked saving in melting-losses were not confirmed, though certain alloys may be more economically treated by the electric method. Some weight must, however, be given to the cleanliness of the electric furnace and the more comfortable operating conditions. In this connection, probably, Patch includes the avoiding of the smoke nuisance, which is certainly a most important matter as regards the public at large. Obviously, as pointed out, cheap electric power will change the relations of the figures; on the other hand, advances may be made in the operation of fuel-firing which will give such methods an advantage over the electric. Alloys sensitive to hydrogen, superheated nitrogen and to carbon will be more satisfactorily treated without fuel.

H. L.

Atomic Weight of Cadmium.—GREGORY PAUL BAXTER and CARL HENRY WILSON, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1230–1241), have determined the atomic weight of cadmium by analysis of cadmium sulphate in the electrolytic way, using a cathode of pure mercury for the deposition of the cadmium. Their results give 112.41 as the minimum value for the atomic weight of cadmium.

J. S. H.

RECENT ADVANCES IN THE PRODUCTION AND APPLICATION OF X-RAYS.*

BY

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THERE have been from time to time during the century past some remarkable discoveries destined to cause profound changes in human thought and mode of life. Some of these have become so quickly and firmly incorporated in our environment that we have hardly realized their origin and rapid development. In theoretical and applied electricity are some of the most striking examples of such developments, having wrought such wonderful results that one can hardly realize their ramifications.

Measured in terms of the duration of human history, all electrical knowledge is recent and most of the practical applications were made within the memory of those who are near to man's allotted three score years and ten. In Denmark there has just been celebrated the one hundredth anniversary of Oersted's discovery of the relationship between electric and magnetic phenomena. A few years after Oersted's work, Henry and Faraday laid the foundation for the marvels to be accomplished in applied electricity. Less than fifty years ago the first power motor made in America was completed and one of the designers is still living. Many of the pioneers in the development of the arc and the incandescent lamp and of the telephone are still active.

Twenty-five years ago this month there was announced a new wonder, the culmination of a long series of experiments, the starting point of a new line of endeavor, giving rise to concepts, unrivalled in scope and daring, and, curiously enough, resulting in theories strangely related to those of the master mind whose honored name is borne by this society.

A careful and well-trained observer, already well known in his chosen field, Röntgen not only announced a type of radiation whose existence had not been suspected but he described, with

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, December 9, 1920.

wondrous simplicity and clearness, experiments performed to ascertain its nature and to properly place it in the scheme of physical science.

I well remember in Dr. E. L. Nichols' physics seminary the mention of a rumor that a radiation had been found able to pass through opaque objects, not capable of refraction or reflection and otherwise strange in its nature. Curiously enough it did not strike us as at all peculiar that light should penetrate glass or water or that radiant heat should pass through opaque hard rubber, but the announcement of rays that would pass through aluminum or the human body was received with hardly tolerant skepticism.

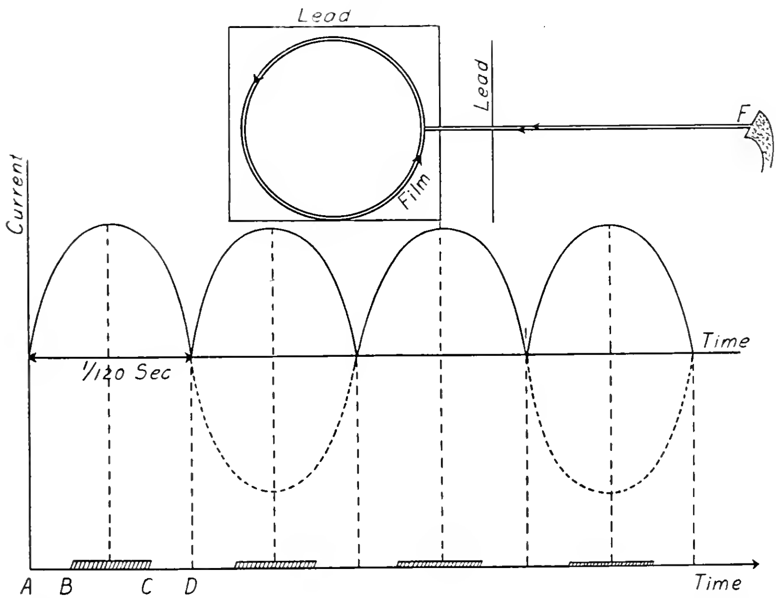
Briefly stated Röntgen showed that peculiar rays were produced by electric discharge through a highly exhausted tube. They were able to excite fluorescent light in certain materials and to affect a photographic plate. They were not refracted or reflected, were propogated in straight lines, and were able to produce secondary rays possessing like properties. Materials varied in transparency to this radiation somewhat in the order of their densities. In his first announcement he was not certain as to the point of origin of the rays or the basic mechanism of their production. He used an induction coil and, initially, tubes that had been designed to demonstrate previously known phenomena. In fact the presence of a card covered with crystals often used in cathode ray tubes led to the discovery.

In a comparatively short time it became clear that the rays originated mainly, at least, at the surfaces of objects within the tubes or in the glass walls, and very soon the curved cathode of Crookes and the metal target gave us the " focus " tube. These early tubes were operated either by induction coils or by " static " machines and carried very little electric energy. The demand for rapid radiography resulted in the development of more powerful coils and the slow evolution of tubes with massive metal targets, water cooling, etc., to enable more rapid work. Meanwhile but little advance had been made in basic theory or in applications outside of medicine and surgery.

Let us consider first the evolution of the exciting apparatus. The early high tension generators had certain inherent complications and limitations. The static machine gave an almost ideal discharge as to steadiness but of very limited quantity.

Also, it was often difficult to get it to function. The induction coil required an interrupter to break a direct current and a properly proportioned condenser to get full output. The wave form might be very irregular as may be seen by oscillograms. There was always more or less "inverse," a source of serious trouble in all tube operation.

Fig. 1.



F target of X-ray tube. A narrow beam of rays passes the lead slits and reaches the film on the revolving cylinder. When a synchronous rectifier is used we have four half waves per revolution as shown by the continuous line.

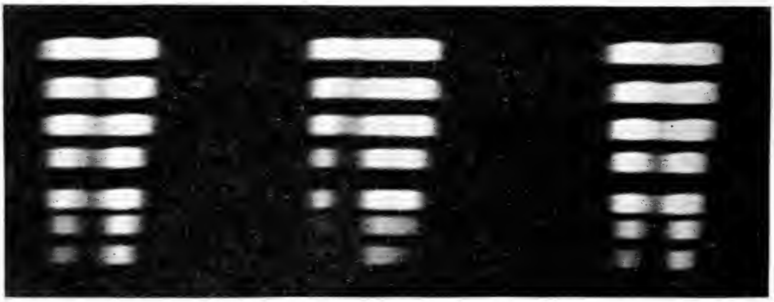
At the instants marked *A D*, etc., there is no tube current and no X-rays. During the time *A B* and again *CD* there is tube current but the voltage is too low to give effective radiation.

When no synchronously driven switch is used the half waves shown as dotted lines are not able to pass through the tube.

The X-ray transformer, developed to operate on alternating current, required a strictly synchronous motor to operate a revolving switch. Such devices were relatively complicated, bulky and heavy and were constructed to deliver enormously more power than could be utilized in practice. Thus a tube may operate on a power intake of 3 k. w., but machines of 10 to 15 k. w. *continuous* rating were supplied, although only a *single* tube was to be operated at one time. Now the output of an X-ray tube is dependent on the current through it and on the voltage drop

between its terminals. The voltage is a much more important factor than the current as the radiation at a given current increases at least in proportion to the *square* of the voltage. During a single set of current changes from no current through all its variation back to no current again there will be, at each instant, some voltage and current, but only when the voltage is high enough

FIG. 2.



A series of exposures using the apparatus of Fig. 1. One exposure has been cut out to shorten the figure. Four exposures result from *one* revolution of the motor.
Note the clear spaces between the dark strips showing that current at low voltage is ineffective. The longest strips were made at 45 k.v. the others at 40, 35, etc., to 15 k. v. An oscillation caused a voltage drop distorting the wave from giving the light areas in the exposed strips.

FIG. 3.

Shows a similar set using a hot cathode tube, self-rectifying. Only two spots per revolution.

for the production of rays able to pass out through the walls of the tube will we get a delivery of X-rays. This is shown by photographing the X-ray delivery on a moving film attached to a cylinder rotated by a synchronous motor and operated on the same circuit as the X-ray transformer. The rays pass through a narrow slit and each area in the photographs shown was exposed 450 times (15 sec.). Note the much greater in-

tensities at the higher voltage *all* other factors, *viz.*, time, current, distance and development being the same. Note also those of a self-rectifying tube, where only two spots appear per revolution.

When we introduce aluminum in the path we find much of the radiation sent out during low voltage fails to pass through

FIG. 4.

One half of the slit of Fig. 1 was covered by 4 mm. of aluminum. On a 6″ gap only ¼ the time was given to the upper portion in order to nearly equalize the exposures. More of the radiation at the higher gap is able to pass through the aluminum.

FIG. 5.

Reduction by absorption of several millimeters of aluminum. 0, 1, 2, 3, and 4 mm. filters used.

even a thin layer. Clearly the most efficient use of electric energy, *i.e.*, the greatest X-ray delivery for a given heat produced at the target would be when all the current is passed at the same potential, *i.e.*, when the voltage is unfluctuating. The work of Hull showed that 2 M. A. at a constant voltage produced radiation identical in all respects to that given by 3 M. A. sine wave. Appliances to give unfluctuating voltages of 100 k. v. or more are

expensive and will probably not be generally used in practice, but will be of enormous value in research and standardization. And it is not at all unlikely that simpler methods may be found to secure at once the highest voltage and a steady output.

Eighteen years after Röntgen's discovery, or in 1913, began what I would designate as the recent period, due to two remarkable discoveries or developments. One the hot cathode tube by Coolidge, the other diffraction of X-rays and resulting interference phenomena by Laue. The former gave us a tube of stable and reproducible performance, the other not only indicated the nature of X-rays but has proved a powerful tool in their application.

Do not conclude that I wish to imply that nothing was accomplished in preparation for these results in the interim between 1895 and 1913. For, starting with Röntgen's experiments there followed the discovery of radioactivity ultimately resulting in the electron theory of electricity, or perhaps I should say, of matter, and the Coolidge tube may be said to be a most perfect application of these new developments. Machines for rectifying high-tension alternating currents had been perfected by Snook and others so that high-power exciters to operate the powerful new tube were already in use.

The Coolidge tube when the anode is cold, *i.e.*, below a few hundred degrees centigrade, permits current to pass in only one direction, *i.e.*, is self-rectifying. Early in 1917 Doctor Coolidge undertook to develop a tube primarily for army use, utilizing this principle and eliminating the synchronously driven switch. In order to carry away the heat developed at the anode he returned to the use of a tungsten button set in copper and utilized an outside radiator also previously employed with gas tubes. This tube was soon known as the radiator type Coolidge, and was used in the U. S. A. portable and bedside outfits. Although limited to 10 M. A. at 60 k. v., or .6 k. w., its performance marked a new era in medical röntgenology. These tubes are now furnished for 30 M. A. and on account of small size and the simplicity of operation are likely to largely displace the "interrupterless transformer" except for therapy. What the future holds for this field one hardly dares to predict, but surely the end is not yet.

Let us now summarize the main features in the production

and the known properties of X-rays as a basis for the consideration of their applications.

1. They are due to the sudden change in velocity of electrons, *i.e.*, small natural negative charges.

2. They travel in straight lines from the points where the electrons are stopped.

3. Their velocity is probably the same as that of light.

4. They are reflected by atoms in proportion to the atomic weight of the atoms struck.

5. They excite relatively long wave-length radiation known as fluorescent light in a few materials.

6. They tear electrons from atoms in their flight, rendering gases conducting by ionization, and causing photoelectric effects in liquids and solids.

7. They affect photographic emulsions in a manner similar to light.

8. They show diffraction spectra analogous to light when a sufficiently fine atomic lattice is used as a grating.

9. The X-ray spectrum depends on the voltage of tube operation and on the target material. No tube giving homogeneous rays, *i.e.*, of a single wave-length, is possible.

10. The atomic reflection in a body whose atoms are not organized into crystalline structure resembles the scattering of light by fog. That of a crystal is similar to crossed grating spectra.

11. There are discontinuous spectra as well as continuous as is the case with light sources. The bright line visible spectrum of the incandescent gas is shown at *sufficiently high temperature* while the characteristic lines of the target material are only shown in superposition on the continuous spectrum when we use a *voltage* above a *minimum*, characteristic of each target material.

12. The distribution of radiation among various wave-lengths and the total amount of radiation is profoundly modified by the voltage used which determines the electron speed. Voltage is here analogous to temperature in black body radiation.

13. The absorption of materials shows discontinuities intimately connected with their characteristic emission spectra. This also is analogous to light, absorption and emission.

14. The *minimum* wave-length emitted is a function of the *maximum* voltage available.

15. The extremely short waves are less easily absorbed and thus effects produced through thick masses or dense absorbers are due to the shorter waves of the X-ray spectrum.

Aside from their action on living cells, X-ray applications are based on (1) the absorption effect of matter varying with atomic weight and thickness, (2) on diffraction effects.

The radiation received on a photographic plate or a fluorescent screen shows shadows, *i.e.*, areas of reduced brightness on the screen or increased transparency on the plate, resulting from either a density exceeding that of surrounding material or greater thickness or both. In the various applications this *variation of opacity* must be *interpreted* in the light of *acquired experience*. The general theory is approximately as follows:

If Q = radiation per sq. cm. falling on the proximal surface

Q_2 = radiation falling on a photographic plate after passing through a thickness d of homogenous material.

Q_1 = that having passed a thickness, d–h, of the above material and *h* c.m. of a denser material.

Assume, what is only approximately true, that μ is the absorption coefficient of the main body and μ_1 that of dense region, where $\mu_1 > \mu$.

$$Q_2 = Q\varepsilon^{-\mu d}$$

$$Q_1 = Q\varepsilon^{-u(d-h)-\mu_1 h}$$

$$Q_2 - Q_1 = Q\varepsilon^{-\mu d}\left[1 - e^{-(u_1-\mu)h}\right]$$

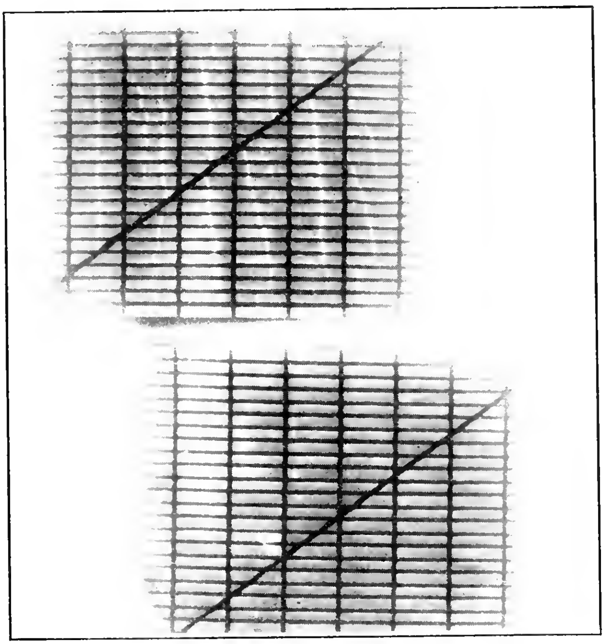
But $Q_2 - Q_1$ must fix the possible contrast between these two areas. This will increase with h, and with the difference in absorption coefficients for the two materials. Since it is also necessary to get some radiation through the body neither *d* nor μ can be too large.

We must then use sufficiently short wave-lengths to affect the screen or plate, but not so high that μ_1 and μ will approach one another. Thus, if all rays were so penetrating as to go through flesh and bone equally well there would *be no radiograph*, also the bodies must not be too thick or $Q_2 = Q_1 = 0$.

But reference to 10 above shows another very important property that always works against the simple theory, *viz.*, rays do not all go straight through but each atom takes a minute toll and sends these rays in other directions, we do not know whether

or not a single atom scatters in a single direction according to its orientation or not, but it is quite immaterial as there are so many in all sorts of positions that there is a general scattering. There results an undershot radiation, falling where otherwise the radiation is more or less reduced and contrast is lost. In only two ways can this action be overcome, first, by reducing the number of atoms causing scattering by using a diaphragm, thus limit-

FIG. 6.



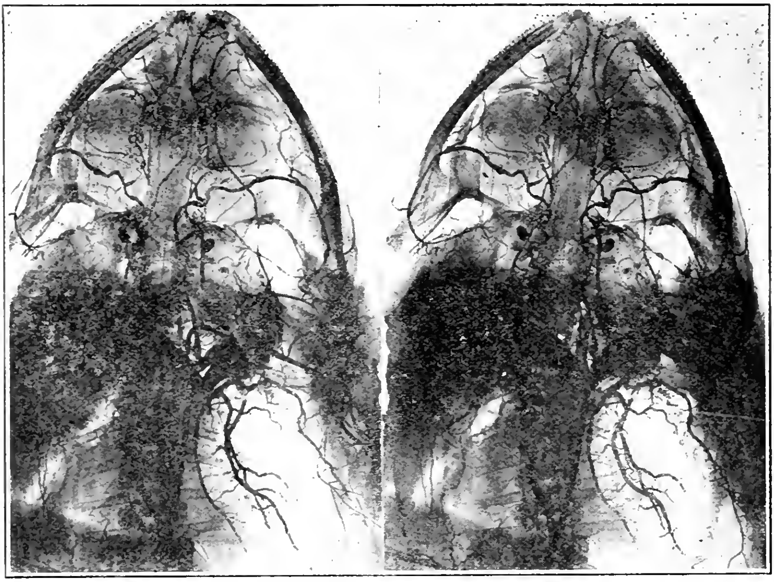
Two storage battery grids. One has several cracks. Some of them not visible in ordinary light.

ing the amount of material acting, or else by using a device originally due to Bucky and recently developed by Potter.

The fluoroscopic and radiographic action depending on the unequal absorption of X-rays at first found application only in medicine and surgery. The advent of the new tube capable of operation at high power for long periods without damage aroused interest in the radiography of various materials some examples of which may be mentioned here: Defects in small castings; grain of woods; defects in manufacture; pieces of metal in various objects. Fig. 6 shows a defective storage battery grid.

Unfortunately both fluoroscopy and radiography have limitations of several kinds, the small thickness of dense materials radiable, time consumed, cost of apparatus, need for protection of operators, physical limits of vision in fluoroscopy, etc., but in many cases such examinations serve to point out defects due to improper processes or to errors readily avoided. Thus to examine hundreds of thousands of copper commutator bars would

FIG. 7.



Circulatory (arterial) system of a frog. Shown by injecting the arteries and then radiographing.

be prohibitive, but to verify the elimination of gas by boronizing samples is relatively simple.

Where inspection can be made readily by fluoroscopy as in cork, mica, and some small objects, it may easily be made a routine procedure.

Our knowledge of animal and vegetable life and structure may be greatly increased by the use of this aid. Note circulatory system of a common amphibian secured by injection of a fluid carrying barium sulphate (Fig. 7).

Turning now to the second great advance that came in 1913 we may consider briefly the phenomena of diffraction. The plane

diffraction grating is doubtless well known to most of you, but perhaps you have not considered the result of using several such gratings in succession on the same beam of light.

If λ = wave-length

d = grating space.

$$\frac{\lambda}{d} = \sin\theta$$

Since $\sin\theta$ never exceeds 1,

there is a minor limit to the wave-length for which a given grating may be used.

$d = \frac{\lambda}{\sin\theta}$, *i.e.*, is always greater than λ.

But if θ is to be, say, 30 degrees, $\sin\theta = \frac{1}{2}$

Then $d = 2\lambda$, Suppose $\lambda = .00005$, $d = .0001 = 10^{-4}$ and we have need of 10,000 lines per cm.

If $\lambda = 10^{-8}$ $d = 2.10^{-8}$

No. lines per cm. $= \frac{1}{2}\ 10^8 = 5 \times 10^7$

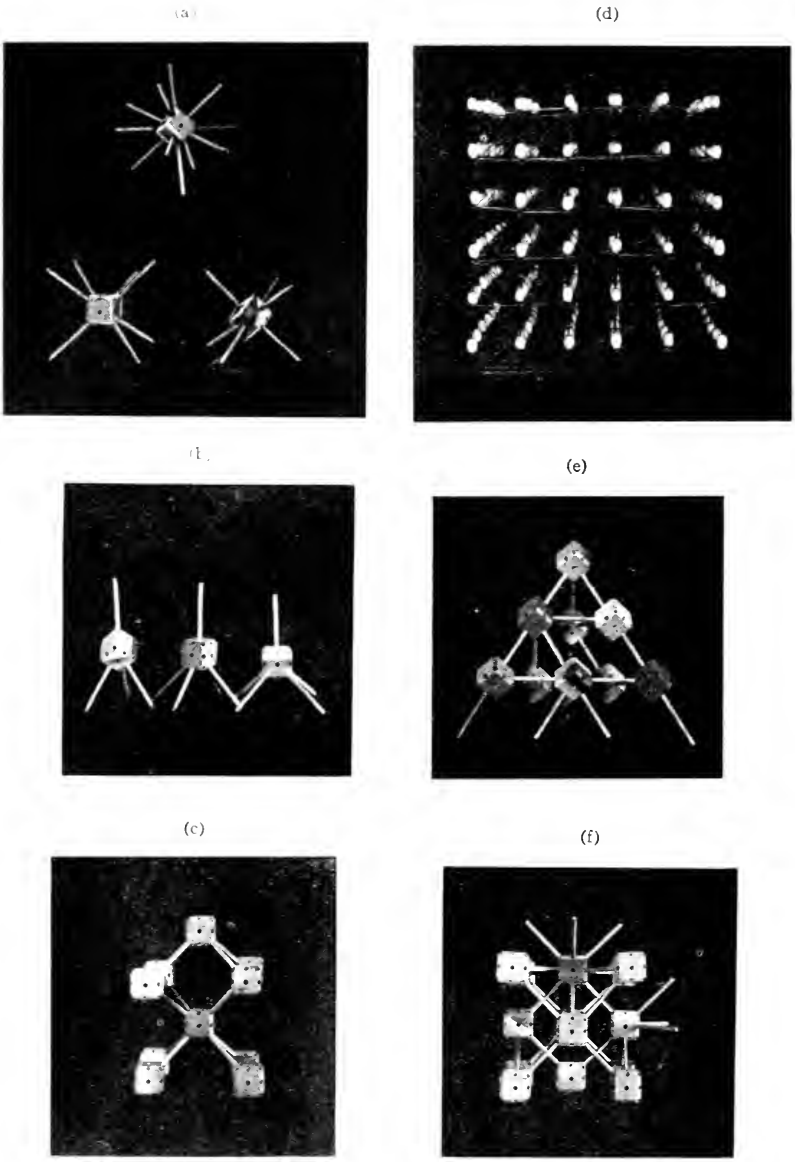
= 50,000,000 or fifty million lines per cm.

One would hardly try to rule as fine lines as this. But an entirely different course of reasoning had shown that crystals were systematic atomic structures, where the atoms were arranged along straight lines with regular spacing. These again formed sets of parallel planes. The fundamental theory of the optical grating postulates the starting of exactly similar waves from each opening at the same instant or at regular time intervals. Laue conceived the idea that each atom might reflect a minute wave element and the regular arrangement of atoms might constitute a space grating for these very short wave-lengths. A simple way of illustrating this will be to build for you a portion of a crystal enlarged in about the ratio of 50 million to one. Thus you see the uniform spacing along lines and that parallel planes may be passed that contain regular atomic patterns (Fig. 8).

Many applications depend on this diffraction of crystals. For in this way we may ascertain two very important things: (1) The presence of elements by identification of their emission or absorption X-ray spectra, or (2) the presence and type of crystalline structure. The original Laue radiographs may serve in part for (2), but hardly for (1). Reflection methods may serve both ends.

Thus the crystal X-ray spectrometer gave us a knowledge

Fig. 8.



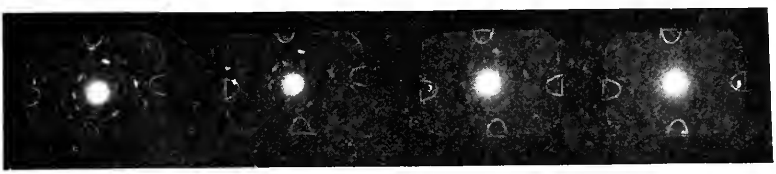
(*a*) Cubical blocks with holes and pegs for use in building crystal models. Holes in the center of each face, the center of each edge and each corner. (*b*) The axial symmetries of such a system, four and three fold. (*c*) Part of a "cubic centered" structure. (*d*) Simple cubic. (*e*) Tetrahedral form of *f*. (*f*) Part of a "face centered cubic" structure.

of the X-ray spectrum and its variation with voltage, then, combined with other methods the rays verified the assumed nature of crystal structure, but even more they told just how the atoms were placed.

True the science of crystallography had been splendidly developed long before X-rays were discovered, but so far as I am aware the exact position of various atoms, and the planes of highest concentration of a given type of atom had not been known. Also, this gives a method for the study of crystals of opaque substances such as metals in a manner not previously possible.

By use of the crystal grating and an ionization chamber the

FIG. 9.



20° 53° 85° 112°

58° 1 hr. 62° 1 hr. 62° 2 hrs. 62° 7½ hrs.

Destruction of crystalline structure of copper sulphate by dehydration.

spectrum of X-ray emission has been studied with reference to the wave-lengths of characteristic spectra and absorption and these results have been verified by photographic methods. An incandescent solid or liquid gives a continuous spectrum varying with the temperature.

A rise in temperature of a hot body adds short waves not present before; increases the intensity of radiation of *all* the wave-lengths present at the lower temperature and shifts the energy peak toward the short wave-lengths. Also an incandescent gas emits a characteristic bright line spectrum that may be superimposed on a continuous spectrum from an incandescent liquid or solid.

Change from temperature, as a controlling factor, to voltage, and we have the same laws in the radiation of X-rays. Further, the characteristic spectra of X-ray emission are relatively very simple and are definitely related to the nature of the atom whose electrical equilibrium has been disturbed at the point of emission. In fact, if we arrange the elements in order by reference to these lines, we shall have with a few slight variations the order of their atomic weight. Here again we break across those accidental boundaries of special sciences to invade the realm of the chemist. We no longer regard the atom as a simple lump of matter but rather as a complex electrical system.

The absorption spectra of X-rays are analogous to those of light. The coefficient of absorption increases with wave-length between two absorption bands. μ/ρ plotted against λ^3 gives a series of straight lines between bands due to the characteristic wave-lengths. Using these results it becomes possible to closely predict how the radiation described by a given spectrum will be distributed in an absorbing medium.

The entire history of an X-ray beam from its inception to its final complete degradation into heat is approximately shown by this chart drawn by Doctor Respondek. The career is surely very interesting and each step might offer a broad field for study.

I have not the time to dwell on that phase of X-ray application, the most widely known, and in some ways the most important, suffice to say the possibilities in the field of medicine are hardly realized to-day, great as we may consider present accomplishments.

Thus has a single epoch-making discovery wrought changes in our lives, our work, our thoughts. How many of the contemporaries of the patient investigators who contributed to the conditions rendering Röntgen's discovery possible realized the importance, or by material support or sympathy encouraged their humble efforts. Yet have these men greatly extended our knowledge with its possibilities for good or ill during a brief century. Sometimes they worked with a definite application in sight, more often were they inspired only by the desire to know more of the world in which man's sojourn is so brief.

That our science and philosophy has been and will still be profoundly modified by these results none will deny, so that these may say as the spirit in Faust,

> "Thus at the ever whirring loom of time I ply,
> And weave for God the garment that thou seest Him by."

REVISION OF SOME OF THE ELECTROMAGNETIC LAWS.

BY

CARL HERING, D.Sc.

Member of the Institute.

The present celebration of the centennial of the important and fundamental research work of those great pioneers, Ampere and Oersted, is an appropriate occasion to note some of the new phenomena or laws, if any, which may have been found and pointed out in recent times, and more especially to examine more critically the laws of such phenomena as commonly stated in text-books and taught in schools and colleges, to see whether they are still universal laws as far as we now know, or whether any modifications are necessary or desirable in order to make them include modern developments or to make them clearer to the student and more easily understood by him.

When a law is a universal one it means that there are no exceptions, hence if there are exceptions it is not a universal law, and its limitations should then be clearly stated or a new law should be framed which is really universal. If a law is really universal it is possible to maintain with certainty that a proposed device or process which violates it, cannot possibly operate; a proposed perpetual motion is an illustration. If, however, a law is not a universal one, though incorrectly so considered, a proposed new device or process might be unjustly condemned as inoperative, thereby preventing progress in new, untried fields. The writer has met with such cases, in one of which a very useful and well-known law, which was considered to be a universal one, was found to call for a result contrary to the facts; the prediction that a certain new device based on this law would operate was therefore found to be wrong. To teach that a law is universal when it has been shown that it is not, is in the writer's opinion an educational crime, specially against the rising generation which is depended upon to develop new and untrodden fields. If a law is really universal it must apply to all future cases. If we know of no exceptions it is excusable, but after exceptions have been found there is no excuse for continuing to maintain that the law is universal.

Moreover if a law is shown to be incorrectly worded it should be revised so as to be correct. In the writer's opinion this is the physicist's duty to the students he is instructing. In a certain case in the writer's experience a well-known law was relied upon as being correctly stated, and much money and time were spent on a device which would have operated had this law been stated correctly, but the device failed completely due to the law having been incorrectly worded.

In another case the laws in text-books were interpreted by physicists to strenuously deny the existence of certain forces, but the writer found that the results of the actions of such forces existed in practice, and therefore required an explanation for their existence. An adherent of the older law made an attempt to explain the result by the aid of hydraulic forces, but the writer believes it can be shown that the text-book law originally relied upon, or as generally interpreted, is not sufficiently comprehensive in scope, and that a new and broader law can and should be framed which applies correctly to all observed facts, and shows that the forces heretofore denied, really exist.

But even if it is possible to explain the existence of some new observed facts in a round-about, cumbersome, complicated way by means of the older laws of our grandfathers, the writer maintains that it is our duty to the student and to the investigator in new and untrodden fields who is relied upon for new developments, to teach him simpler and broader laws which apply more directly, if such new laws can be framed and are correct.

LIKE CURRENTS ATTRACT.

An old and well-known law, given in every text-book on electricity, is that " like currents attract and unlike repel." This law is not correct as stated. If it were it would necessarily have to follow that the current density in a conductor would have to be greater near the centre than near the periphery, as a current can be considered as made up on a large number of filamentary parallel currents which would attract each other toward the centre. Yet we know that this non-uniform current density does not occur. Or a current from a flat anode to a flat cathode in an electroplating bath would have to cause a denser deposit in the middle of the cathode, which we also know is not the case. Moreover if this law were true the pinch effect mentioned below would not exist, yet we

know it does. Furthermore, two parallel cathode rays passing in the same direction in a vacuum tube will be found to repel each other, which they should if they consist of like charges moving in neighboring paths; this shows directly that like currents really repel each other, when there are no conductors.

The change which should be made in this law to make it apply correctly is to state that these attracting and repelling forces act on the *conductor*, that is, on the material of the conductor, and not on the currents *per se*.[1] The pinch effect shows conclusively that it is the material of the conductor and not the current *per se*, which is moved to the centre by this force. In most cases this distinction between the currents and the conductors is of no consequence, but there are cases in which it is of prime importance, and a law to be universal must include all cases. This distinction is also of interest because an analogous one must also be made in electromagnetic induction, as will be described below, and perhaps in a third case also.

These forces between neighboring current-carrying conductors may be explained as being due to the action of the magnetic flux which encircles them, but it should be noted that this flux acts chiefly on the conductor and not merely on the currents.[2] If it acted chiefly or entirely on the currents it would follow that in the case of two closely adjacent conductors and a constant, direct current, one-half of each conductor would have more current flowing through it than the other half, which it is believed is not the case, except to the slight extent due to the Hall effect.

THE PINCH EFFECT.

Some fourteen years ago the writer, relying on the correctness of the older law, concluded that any metallic conductor could be kept melted in an open channel by simply passing a sufficiently large current through it. He found, however,[3] that this was decidedly not the case, as a sharp limit to the current was reached at which the liquid conductor contracted at one point (always the point of minimum cross section) forming a V-shaped valley which

[1] Maxwell's Treatise, vol. ii, art. 501.

[2] The Hall effect, the existence of which Maxwell denies (Sec. 501), shows that it acts on the currents also, it seems to act in this way when the conductors are not free to move. A definition is given in Northrup's "Laws of Physical Science," p. 159.

[3] *Trans. Amer. Electrochem. Soc.*, vol. 11, 1907, p. 329; also vol. 15, 1919, p. 255.

generally descended quickly all the way to the bottom of the channel, which in this case was about six inches deep and contained molten iron. This of course broke the circuit; the current having ceased, the molten metal flowed together again and was immediately parted again, spitting forth globules of molten metal as from a miniature volcano. Fig. 1 shows about how it appeared just prior to a rupture, *E, E* being the solid electrodes.

FIG. 1.

The appearance of this V-shaped depression ending in a complete rupture was as though a hugh invisible pinch cock was severing the liquid column as it does when in a rubber tube, and for this reason the writer colloquially gave the phenomenon the name "pinch effect," by which it has since become generally known here and abroad. The term is not a misnomer, as has been alleged,[4] as it describes better than any other one word could do, the appearance of the phenomenon as it is generally seen to occur in open channels.

It can be explained either by saying that the radial contraction of the encircling flux crushes the yielding liquid conductor to the point of severing it; or that the filamentary conductors carrying like currents, attract each other to the vanishing point; the latter would not be true if this electromagnetic force acted on the currents as the older law states, as distinguished from the material of the conductor.

This force has been termed an internal one in order to distinguish it from the forces acting on a conductor from something external to it, like a second neighboring conductor or a magnet, which latter kind of forces, as observed by Ampere, Oersted and others, are elaborately described and discussed in text-books, to the almost complete exclusion of others. To the student this crushing force may be explained as being apparently caused by the contraction of the well-known external flux surrounding it; the internal flux is not so well understood. To call it the "self-crushing" force would seem to be more appropriate and more self-explanatory. The intensity of the flux at any point inside or outside of a conductor, sup-

[4] This Journal, Dec., 1920, p. 833.

posedly represents the *resultant* intensity, at that point, of the flux as a *whole,* inside and outside; hence both contribute to this crushing force. It is true, however, that in the resulting contraction of the conductor only the flux which was inside is cut, and therefore that alone need be considered in quantitative mathematical deductions.

It may be of interest to add here that in the C.G.S. system the writer has found [5] that the quantitative relation of this force to the current and to the circular section when the conductor is far removed from all flux foreign to it, is a unit relation, $P = I^2/S$ in which P is the pressure at the centre in dynes per sq. cm., I is the current in C.G.S units, and the cross section S is in sq. cm. It is therefore not a direct function of the current density alone.

This contraction is accompanied by a very marked movement of the liquid conductor in the direction of the axis as shown in Fig. 1. This was at first thought to be a hydraulic resultant of the radial pressure. It will be shown below that there are good reasons to believe that there exists also a self-produced stretching force. This contracting force is also influenced very greatly by neighboring external currents and magnets. Electric furnaces in which these forces and others are relied upon to expel the molten metal from resistors in which the heat is developed in the metal itself [6] are in use in large numbers.[7] Fig. 9, described below, shows diagrammatically one of the earlier types.

MAXWELL'S LAW OF INDUCTION.

Maxwell's well-known and much-used law of electromagnetic induction, as stated in most and probably all text-books, is based on the altering of the amount of magnetic flux in an electric "circuit" (Maxwell's own term), that is, on the linking and unlinking of the magnetic and electric circuits. This law is the basis of the calculation of all of the usual electric generators, motors and transformers, and seems to be considered as the fundamental, universal, law of induction.[8] It was therefore supposed that it could be relied upon as being a universal law, that is, without any exception.

[5] *Metallurg. and Chem. Eng.,* vol. 9, Feb., 1911, p. 86.

[6] This Journal July, 1911, p. 64.

[7] This Journal Oct., 1920, pp. 499-500.

[8] Maxwell, Sec. 541, says we can "enunciate completely the true law of magneto-electric induction" in this way.

It was thus relied upon by the writer more than a dozen years ago, in devising a new induction apparatus which would have had some very valuable properties, but from previous experience with the incorrect statements of such laws in text-books, it was thought best to test this law first with a simple crucial experiment. This test [9] showed that any or all of the flux included in a closed electric circuit could be removed (and replaced) without inducing any electromotive force whatsoever, and of course, without opening the

FIG. 2.

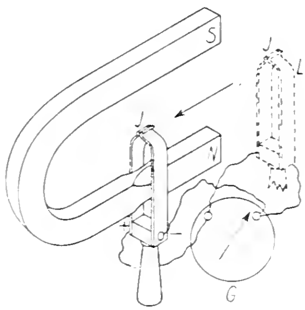
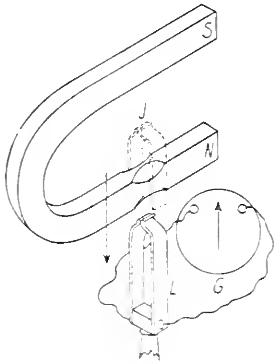


FIG. 3.



circuit. Maxwell's own statement of his law,[10] as also the various versions of it by others, when read on this experiment require that induction must take place. Hence this experiment violates his law, and is therefore an exception: and the law is therefore not a universal one, and can no longer be relied upon as such. This is believed to have been the first demonstration of an exception to this law.

Figs. 2 and 3, taken from the original paper, show that when the circuit or loop *L* was linked with the flux in the usual way, as shown in Fig. 2, there resulted the expected induction, as shown by the deflection in the galvanometer *G*. But when unlinked in the manner shown in Fig. 3, there was not the slightest induction; the circuit, of course, was closed all the time. The circuit cut the flux but the conductor did not.

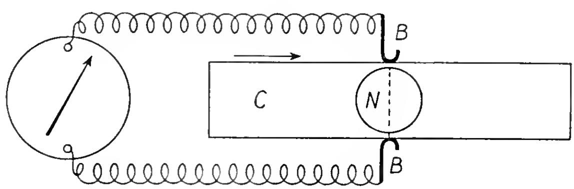
[9] *Trans. Amer. Inst. Elec. Eng.*, vol. 27, part 2, 1908, p. 1341. The original, crude apparatus was deposited, by request, in the museum of the Franklin Institute.

[10] Vol. 2, sec. 531 of his well-known Treatise. Also Northrup's "Laws of Physical Science," p. 145.

At the writer's suggestion C. P. Steinmetz then formulated a new law,[11] which it seems can be relied upon as being universal, and it is probably the first time such a law which is really universal was ever formulated.

The point brought to light by this experiment is analogous to the other case cited above, that it is again very necessary to make a distinction between the conductor itself and the circuit *per se*. Such a distinction was not made in this case by Maxwell, who refers only to the "circuit" as he himself calls it. As magnetic flux necessarily forms a closed circuit which cannot possibly be "opened" like an electric circuit, it follows that in "altering" (to use Maxwell's

FIG. 4.



own term) the amount of flux in any closed electric circuit, the flux must "cut" across the circuit, to use Faraday's term. The distinguishing feature in this experiment is that the conductor itself does not cut across the magnetic flux, although the "circuit" does.

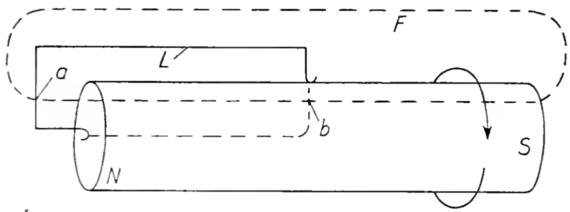
If Faraday had made one more variation of one of his classical experiments than he did, he would have noticed this distinction, and his follower Maxwell would presumably have modified his own statement accordingly. In this experiment by Faraday,[12] shown in Fig. 4, a copper strip *C* was drawn across the face of the pole of a stationary magnet *N*; two fixed brushes *B B* connected to a galvanometer, completed the closed electric "circuit" across a part of the strip, as shown by the dotted line which the present writer has added. On moving the strip he found a current was induced. Had he moved the magnet while the strip and the brushes were at rest, he would also have obtained a current, and it would have been an exact demonstration of Maxwell's statement of the law, as the

[11] *Trans. Am. Inst. Elec. Eng.*, vol. 27, part 2, 1908, p. 1362.

[12] Faraday's "Researches," 1831. Fig. 16. Plate III, described in paragraph 101, and re-produced in an article by the writer on "A New Fractor in Induction; the 'Loop' vs. the 'Cutting Lines of Force' Laws," in the *Elec. World*, vol. 51, March 14, 1908, p. 559.

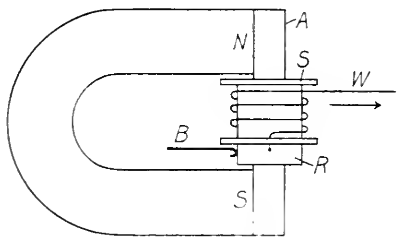
amount of flux within the "circuit" would have been "altered." But if he had in this latter variation, moved both the magnet and the strip together, Maxwell's law should have applied as before, as the flux within the circuit was altered precisely as before, but there would not have been the slightest induction, as the material of the conductor did not cut across the flux although the circuit did.

FIG. 5.



Faraday's other classical experiment shown in Fig. 5, with a magnet *N S* revolving on its axis, and a stationary loop *L* connecting the centre of one pole with the middle of the magnet, would also have shown this distinction, when properly analyzed. The electric circuit is here shown as it is completed through the magnet; the same flux *F* is necessarily cut twice by the circuit, in its two opposite directions, at *a* and at *b*, and would therefore produce no resulting induction were it not for the fact that in one of these

FIG. 6.



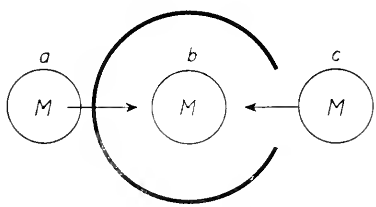
transits across the flux the conductor itself does not cut the flux, though the circuit does. This is true whether the flux revolves with the magnet or is supposed to be stationary in space.

There is another striking experiment shown in Fig. 6, which also violates the Maxwell law, much to the surprise of some who tried it. If a few turns of a coil of flexible wire be wound on a spool *S*, revolvable over an iron core axis *A*, there will of course be induction when the poles of a magnet are brought to the ends of

the iron core, as the flux and the coil will thereby become linked. But if now the wire W be pulled off tangentially to the coil, the spool revolving on its axis, the contact with the inner end being made by means of a slip ring R and a stationary brush B, there will not be the slightest induction although the flux and the circuit have thereby been completely unlinked, while the circuit remained closed by the measuring instrument. No part of the conductor has cut any of the flux.

Still another experiment, but one which is difficult to carry out, is to form a nearly closed circuit like the letter C, Fig. 7; then by passing the flux from a magnet M across the conductor from the

FIG. 7.



position a to b a difference of potential should be found to have been produced at the two open terminals of the circuit; this will probably not be denied; the flux and the nearly closed circuit have been linked thereby. But if the same flux were passed through the open part of the circuit from c to b, being brought to the same position b within the circuit as before, therefore producing the same ultimate linkages as before, it will no doubt be admitted that there would be no induction. In the one case the flux was cut by the conductor itself, and in the second case it was not. A unipolar generator might be constructed on this principle if the poles of a revolving magnet be made annular and moved so that the flux enters through the opening of the C and leaves across the conductor, the circuit being always closed across the opening by brushes touching the circular core.

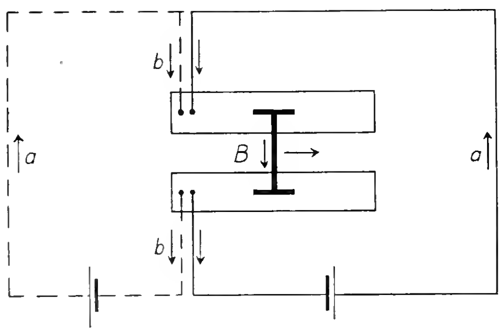
These experiments also show, what Maxwell's law fails to show, that the actual induction takes place at, and only at, that part of the conductor which cuts across the flux, and not in general all around the circuit as Maxwell's words, "an electromotive force acts round the circuit," have been interpreted to mean; the rest of the circuit is a mere dead conductor, as far as any induction is con-

cerned, as was shown experimentally by the writer many years ago.[13]

THE STRETCH EFFECT.

The writer's researches with the pinch effect a number of years ago led him to the belief that there should also exist a complementary force axial to the conductor and also produced by the current in the conductor itself as distinguished from being caused by external currents or magnets. Just as the pinch effect tends to crush the conductor radially reducing its cross section, so this other force tends to stretch the conductor axially, thereby tending to in-

FIG. 8.



crease its length, somewhat like a spiral spring which had been compressed axially, except that this stretching force should theoretically continue without limit as the conductor yields to it, and in fact it presumably even increases if this stretching diminishes the cross section (as it sometimes does; see Fig. 1), just as the pinch effect increases as its effect on reducing the cross section increases. The name of "stretch effect" was given it, and the reasons for its existence were described by the writer at that time.[14] Some experiments were there described, the movements in which were predicted on the basis that such a stretching force exists, but were contrary to what they should be according to the older theories.

One of these, a modified form of the well-known Ampere mercury trough experiment, is reproduced in Fig. 8; the dotted circuit shows the way the experiment is usually carried out. One

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[13] "The So-called 'Dead Wire' and Gramme Armatures." *Elec. and Elec. Eng.*, vol. 6, May, 1887, p. 171.

[14] This Journal, Jan., 1911, p. 73.

of the usual explanations is that the movement of the floating bridge piece B to the right is due to the fact that every circuit tends to expand. Another is that the current in B, being opposite in direction to that at a, they repel each other; an inquiring mind, however, will ask why B is then not attracted to the left by the like currents at b and b which are much nearer to it.

The writer's explanation is that every circuit tends to lengthen or stretch itself, as that increases the amount of flux (thereby generating a counter e.m.f.) in proportion to its increase in length, if far removed from all other circuits, and if the stretching does not decrease the cross section.[15] The only part which has a freedom of motion lengthwise is the part in the mercury troughs, which part therefore lengthens. As the counter e.m.f. developed thereby is due to the flux which has been added by this increase in length, the real seat and origin of this force should be attributed to this tendency to stretch and not primarily to the interaction of the two conductors at right angles to each other; the latter is really a resultant secondary force.

To show that both of the older explanations are in error, the writer reversed the battery loop as shown in full lines in Fig. 8, and found that the direction of motion of B was, as predicted, the same as before, when it should have reversed according to both of the older theories. The area embraced by the circuit now actually contracts, and the stretching force is greater than the combined attraction and repulsion of b b and a. The return circuits in this test must not be too near the troughs.

It is thought that both the crushing and stretching are merely different manifestations of the same prime cause, namely the flux surrounding the conductor and produced by its own current. This encircling flux tends to contract around the conductor, thereby tending to crush it, and the parallel elements of this flux in planes perpendicular to the conductor, tend to repel each other, thereby tending to stretch the conductor. Both motions are very pro-

[15] In a paper on "Ampere-Centimeter, a Measure of Electromagnetism," read by the writer before the Electrical Section of the Franklin Institute in 1892, published in this Journal, vol. 134, p. 69, it is shown that for a filamentary conductor (having no appreciable thickness) and removed from all external currents or magnets, the amount of flux encircling it per ampere per unit of length is constant. Hence for a material conductor the flux increases in proportion to the length, if not influenced by other external conductors or magnets. Amount of flux is the same kind of a physical quantity as current x length.

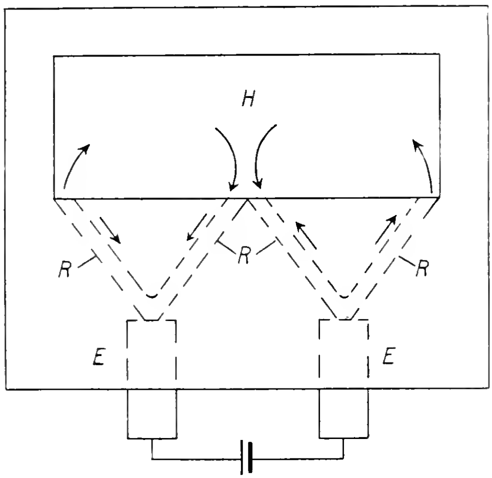
nounced when the current densities are great, and if they are the same phenomena it may not be safe at present to say which is the primary one and which the secondary or resultant one. Reasons will be given below why it is thought by the writer that the prime cause of both is the same, and that either or both movements will result depending upon which are mechanically possible from the nature of the conductor and its surroundings. For instance, in a circumferentially enclosed channel immersed deeply below the surface of a bath of metal, in which rupture by the radial contraction is prevented by the hydraulic pressure, the axial movement (stretch effect) is very strong and decided; while in a short open channel with solid walls at the ends limiting the stretching, the transverse crushing (pinch effect) is most marked. But either one could explain both movements if the other is assumed to be a hydraulic resultant.

No quantitative relations have as yet been deduced for this stretching force, but it is likely that it increases with the square of the current, and is some inverse function of the cross section. It could be stated either as a force or (as in the case of the pinch effect) as a pressure, and is probably in its simplest form for a circular section; the formula for the pinch effect becomes highly complicated for any other form of section. It must also be assumed that there are no fluxes foreign to that of the conductor itself, as such foreign fluxes no doubt have very pronounced effects. The stretching force is assumed to be due to the mutual repulsion of the disks of flux around a conductor, and presumably the flux in the interior also contributes its share. The stretching may sometimes give rise to a contraction of the cross section, as in a curved band of mercury on a flat table, resulting in an ultimate rupture at the weakest point where the stretching force becomes greatest. It is even conceivable that this stretching force might become so great that a straight, though very flexible, conductor like a liquid, might double up on itself somewhat like the letter S, which gives a greater length between two stationary points; we know that a long spiral spring under compression tends to assume such shapes if thereby it can lengthen itself.

But some physicists strenuously maintain that all electromagnetic forces acting on a current-carrying conductor, whether produced in the conductor itself or by neighboring conductors or magnets, must of necessity always be perpendicular to the axis of

the conductor, and can therefore never have a resultant in the direction of the axis.[16] Over a dozen years ago when the writer was making researches in which such axial movements of the conductor were very pronounced, it was alleged by others that axial electromagnetic forces were not known to the art, and could not possibly exist. But the observed results required an explanation.

FIG. 9.



THE CORNER EFFECT.

At that same time the writer noticed that in an open channel containing mercury and making a right angle corner, there was a very marked mechanical agitation at the corner, and with a current that was apparently not great enough to disturb the metal in the two channels forming the corner; he therefore called it the "corner effect," and concluded it was due to the mutual electromagnetic effects of two neighboring current-carrying conductors inclined to each other. It was at that time explained to others, including G. H. Clamer and the writer's assistant, James Wyatt, of the Ajax Metal Company, and together we then constructed a furnace at those works designed by the writer, based on the interaction of two

[16] Maxwell's Treatise, vol. 2, art. 505-508. Also Northrup's "Laws of Physical Science," p. 152, par. 3: "If a wire carries a current no external magnetic force can so act upon the wire as to tend to make it move in the direction of its length." Presumably no distinction was intended between external and internal magnetic forces.

conductors inclined to each other, with the object of producing a unidirectional flow through the resistors. The result was as predicted by the theory. A number of years later this same force was given by others [17] the name "motor effect," which, however, is not a proper distinguishing name, as all of these several forces which produce motion are equally well entitled to this name; its original colloquial name "corner effect" has at least the redeeming feature of more clearly specifying it and distinguishing it from the others.

The action in this furnace is shown diagrammatically in Fig. 9, which is a view from the top. *H* is the hearth of liquid metal. Near the bottom are four horizontal holes *R* the liquid metal in which constituted the resistors in which the heat was developed by the current passing through them from the solid electrodes *EE*. The above mentioned electromagnetic forces were relied upon to expel the heated metal very rapidly into the hearth, cooler metal flowing in to take its place. The directions of the observed flow of the metal, which had been predicted by the writer, are shown by the arrows in the hearth *H;* this flow in the directions of the axes was very strong and decided; the directions of the electric currents (for one half wave of an alternating current) are shown by arrows next to the resistors *R*.

AXIAL FORCES.

It was again alleged by physicists that none but perpendicular forces can exist, and an effort was made [18] to show that the axial flow was due to a resultant hydraulic force. When two conductors carrying like currents are parallel to each other they will attract each other, but it has been denied that when they are inclined to each other and are mounted so that they are free to move only in the direction of their axes, this same attracting force has any tendency to move them lengthwise as they would if they were magnets.

The explanation originally offered by the writer is borne out in Ganot's well-known and generally reliable "Physics," [19] in which the resultant electromagnetic force between two current-carrying conductors at right angles to each other, is shown to be along a

[17] This Journal, Oct., 1920, p. 491, and Dec., 1920, p. 817.

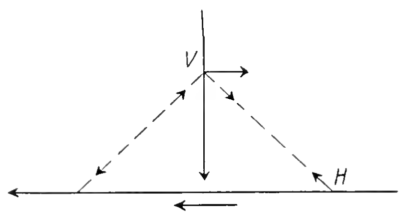
[18] This Journal, Dec., 1920, p. 817. Also E. F. Northrup's "Laws of Physical Science," p. 143 (published many years later and after the writer had explained the observed results to him).

[19] Eighth edition, p. 740, art. 835; or twelfth edition, p. 811, art. 862.

diagonal line across the corner as in Fig. 10. It necessarily follows from this that there is a component of this force in the direction of the axis of each of the conductors, hence an axial force. And as this referred to wires there could not have been any hydraulic action.

But there is also a direct demonstration. In the old and classic experiment referred to in Ganot by this diagram, Fig. 10, the apparatus for which probably exists in most well-equipped physical lecture rooms, a vertical conductor V was mounted so that it could

FIG. 10.



move only parallel to itself, hence only by a force perpendicular to it; the other conductor H beneath it was horizontal and stationary. When current was passed through both, the vertical one moved parallel to itself in the plane of H and V, thereby showing the accepted perpendicular force. This experiment is thought to be attributed to Faraday.

It seems strange, however, that during the nearly hundred years since, it has not seemed to have occured to any one that as this force was relative to the conductors it must necessarily follow [20] that if the same apparatus were reversed so that the vertical conductor was stationary and the horizontal one so mounted that it could move only in the direction of its axis, it would so move, thereby showing the existence of the axial force heretofore so strenuously denied by some physicists. There seems to be no apparent reason why this should be an exception to Newton's third law. This reversal was tried by the writer and shown to others; the action was as predicted.

The well-known and classical Ampere trough experiment, Fig. 8, already referred to, affords another and in some respects better way of demonstrating this. If this apparatus be reversed in

[20] Newton's third law of motion, "To every action there is always an equal and contrary reaction." Northrup's "Laws of Physical Science," p. 3.

the sense that the bridge wire is now made the stationary part and the whole of the rest of the circuit is mounted so that it can move parallel to the axis of the troughs, it should move in that direction according to Newton's third law, thereby again showing the existence of the axial force denied by physicists. And as the mercury could be replaced by solid wires with sliding contacts, the action cannot be hydraulic.

These experiments again show, analogously to the others, that the action is on the material of the conductors and not on the currents *per se* nor on the flux. The flux at a corner is distorted and this gives rise to forces, but these act to move the conductors and not merely the flux.

REVOLVING A CONDUCTOR AROUND ITS AXIS.

If this same principle of reversing an experiment by making the stationary parts movable and the movable parts stationary be applied to a curious experiment described by E. F. Northrup, it could be shown that an odd internal electromagnetic force exists which tends to revolve a conductor continuously around its own axis. Few if any would have suspected the existence of such an odd force; nor is this a force perpendicular to the conductor, in the sense of tending to move the whole conductor parallel to itself. It is dangerous to claim that forces differing from those known to Maxwell cannot possibly exist. According to Maxwell the Hall effect could not exist, yet it does.

In this experiment of Northrup's [21] a magnet with like poles at the ends, and the other pole in the middle, is mounted horizontally so that it can revolve in a horizontal plane around a vertical axis. It is placed in a cylindrical jar slightly larger in diameter than the length of the magnet. The jar is filled with a good conducting electrolyte. When a current is passed lengthwise through the jar the magnet will revolve, hence it would have to follow from Newton's third law that if this magnet were stationary the conductor (the liquid) would have to revolve around its own axis. No hydraulic force is involved. It is based on the magnetic flux in the interior of a conductor.

The present writer has also shown [22] how this same device

[21] *Physical Review,* vol. xxiv, no. 6, June, 1907, p. 480.

[22] "Direct Currents in Electrolytes without Electrodes." *Trans. Amer. Electrochem. Soc.,* vol. 13, 1908, p. 273. The Northrup apparatus is illustrated in this paper.

could be made to generate a continuous direct current in an electrolyte without the aid of electrodes, which was thought by some to be impossible. This could be done by forcing the magnet to rotate, which would generate a current in the interior of a circuit consisting entirely of an electrolyte; the magnet can be insulated from the electrolyte. It is probably not adapted for practical application.

MOVING FLUX.

It is admitted that when a magnet is moved about irregularly in space the flux moves with it, but it is maintained by some that when the magnet is revolved around its own axis, is a perfect cylinder, and is uniformly magnetized, it forms an exception as the flux is then claimed to remain fixed in space, in the sense that there would be no induction in a stationary wire radial to the conductor; in Fig. 5 the induction then would be at *b* and not at *a*. Similarly if a current-carrying conductor be moved axially, its encircling flux would not move with it, and would not cause induction in a stationary wire radial to it.

It is difficult to determine this experimentally because any closed circuit would be cut a second time by the same flux reversed. But by using mercury drops to carry the induced charges from such a conductor to a condenser, during the second transit through the flux, it would seem to be possible to determine it. In the writer's experiment based on Fig. 10, in which there was an axial motion of the wire *H*, a counter e.m.f. was presumably induced in the vertical wire *V* which multiplied by the current represented the kinetic energy which was being set free. It would seem that this counter e.m.f. was induced by the flux which encircles the moving wire *H* and cuts the vertical wire *V*. If so, the flux moves with the wire.

It would assist in analyzing some of these odd cases, to know whether the flux moves with its material source or not. If it does then it must move with a conductor which moves axially.

GENERAL CONCLUSIONS.

The general conclusion, to be drawn from these observed results in the several cases described above, is that some revisions are necessary in several of our laws of electromagnetism; this seems preferable to the more or less desperate attempts which have been made to put the older laws through what might well be called con-

tortions, in order to try to make them still fit these exceptions. It is our duty to the student and coming generation to make these laws universal, as far as we know now, therefore making them apply to future cases as well, and to state them so that they not only can be easily understood, interpreted and relied upon, but also that they cannot be misunderstood. The engineer, who applies these laws, looks to the physicist to state them clearly and correctly.

One of the points brought out by these observed results is, as was stated, that a clearer distinction is necessary between the material conductor and the more subtle circuit, current, and flux. The other is that, in the opinion of the writer, it seems possible to frame a more general law, which as far as is now known seems to cover all the known cases, old and new, of the actions of electromagnetic forces on conductors. The writer ventures to suggest that such a law could be based on the following considerations.

There is a general principle in mechanics [23] that in any system such motions will tend to take place as will reduce the potential energy of the system. What particular motions will actually take place depends of course on the mechanical freedom which the parts may have. A weight will reduce its potential energy by falling directly to earth, or along an inclined plane if such a plane interferes with the vertical fall, or along a curve if it is mounted as a pendulum; water will flow down hill through tortuous paths, including a syphon; a body moving rapidly enough eastward could decrease the potential energy of the earth by moving rapidly away from it against gravity, owing to centrifugal force. Although gravity acts only vertically, the motions to reduce this kind of potential energy may be various. The potential energy which is thereby lost is converted into kinetic energy and appears as work done by the system. If during these motions this amount of kinetic energy is being continuously replaced to the system from some external source, the motion will continue even though there is then no further reduction of potential energy thereby. Thus from an elevated water-tank the water will flow downward to reduce its potential energy, even though the tank is being kept full by a pump whereby the potential energy of the system is maintained constant.

This general law should apply equally well to a system con-

[23] J. J. Thomson, "Elements of Electricity and Magnetism," p. 82, reprinted in Northrup's "Laws of Physical Science," p. 7.

sisting of a current-carrying electric circuit, the current being considered merely as that which produces the potential energy. If so, then it follows that any motions of the conductors will tend to take place which will tend to reduce what might properly be called the potential energy of the circuit; it seems unwarranted, therefore to limit these motions to any particular kinds or directions, provided only that they are such as would, if they took place, reduce the potential energy of the whole circuit. A liquid conductor will naturally respond more readily to some of these forces than a solid one, and secondary hydraulic forces might sometimes be developed in them, as in Fig. 11 described below. In an electric circuit any and every motion which changes potential into kinetic energy it is believed must necessarily generate a counter e.m.f. which if multiplied by the current flowing (if in phase) is the kinetic energy. Hence in general it seems that any motion which generates a counter e.m.f. will take place if the conditions of freedom exist; there should be no further restrictions as to any particular directions. If this counter e.m.f. is then continuously balanced by increasing the direct e.m.f. of the circuit by an equal amount, the same motion will continue if its freedom is continued, without a further reduction of the potential energy of the system. A circuit with a motor or a furnace,[24] like that in Fig. 9, is an illustration.

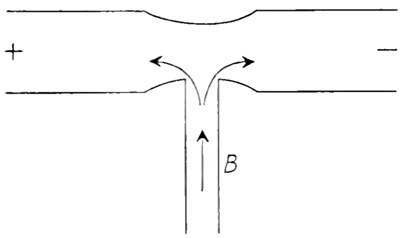
Such a general law would seem to explain and justify all the various observed motions be they perpendicular, inclined, axial (longitudinal, therefore including the actions of neighboring conductors and the corner effect), radially contracting (the pinch effect), longitudinally expanding (stretch effect), a continuous motion which produces no ultimate deformation of the circuit (though producing a counter e.m.f.), and no doubt any other motions not yet observed.

When two neighboring conductors with like currents move toward each other some flux is cut, producing a counter e.m.f.; the same when they move away from each other due to their repulsion. When the pinch effect acts, the internal flux is cut, producing a counter e.m.f. When a conductor elongates itself, additional flux is added to the system, which produces a counter e.m.f. When a

[24] In one of the writer's electric resistance furnaces, in which hundreds of pounds of molten brass were continuously being set into rapid motion lengthwise to the axis of the channels, this counter e.m.f. was found to be about 50 per cent. of the total, and represented nearly 50 kilowatts.

conductor like H in Fig. 10 moves axially near another, V, making an angle with it, flux is cut, producing a counter e.m.f. It may not always be easy to explain how the flux is cut, but the very fact that the potential energy of the circuit produces motion and therefore converts some of its potential energy into kinetic, seems to mean that a counter e.m.f. must be produced thereby. A movement toward or away from a denser field of flux must cut some flux. It seems even that a motion of one part may take place without generating any counter e.m.f. in that part, if by such motion changes of flux can take palce which generate a counter e.m.f. in another and

FIG. 11.



stationary part of the same circuit. The movement of the bridge piece B in Fig. 8 seems to be an illustration, as the seat of the counter e.m.f. must be in the lengthened parts of the mercury troughs which are stationary, not in the moving part B. In general it seems unsafe to restrict these self-produced motions any more than that they must reduce the potential energy of the circuit, which it seems can be done only by producing a counter e.m.f. in some part of the circuit.

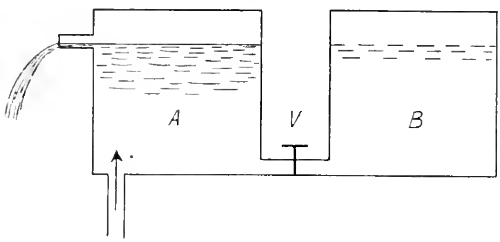
In liquid conductors there are of course likely to be some evidently secondary motions which are purely hydraulic. For instance, in a tube or channel having a branch B, as shown in Fig. 11, both the tube and the branch being in a horizontal plane, there will be a decided motion in the branch B, due to the suction caused by the pinch or stretch effect in the main tube. The fact that the liquid while it is still in the branch is not a part of the conductor, shows that the motion is due to hydraulic forces. Even when a current does flow through B also, there will be some purely hydraulic forces when the radial contraction in the main tube is greater or less than the axial pressure in the branch B.

In the application of this general law to a current-carrying elec-

tric circuit, there is, at first sight, an apparent contradiction in some cases, in that the circuit as a whole may have *greater* potential energy instead of less, after the motion has taken palce, than it had before; this may be the reason why this general law has not before been applied to electric circuits to explain the observed motions. That this is not really a contradiction but only apparently so, is perhaps best shown by the following mechanical analogy:

In Fig. 12 let *A* be a tank which is constantly being kept full to its overflowing level by a pump, that is, by kinetic energy. The

FIG. 12.



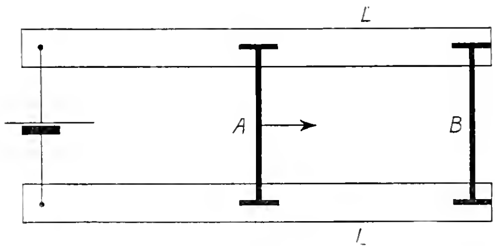
water in it may correctly be said to have the same potential energy as though in a static condition, that is, as though both the supply and the overflow ceased. Hence when a valve *V* is opened, it is the tendency to reduce its potential energy that causes the water to flow into the second tank *B*. There will be a temporary drop of the water level in *A*, but if during this flow the pump keeps supplying water continuously to the tank *A*, the tank *B* will ultimately be filled to the same overflow level as in *A* originally. The final potential energy of both the tanks together will then be greater than it was originally in *A* alone, yet the *cause* of the flow into the tank *B* was nevertheless the tendency of the potential energy of the tank *A* to reduce itself; the general law of mechanics has not been contradicted; the additional potential energy of the tank *B* has been supplied by the pump.

Similarly, in a current-carrying electric circuit, the potential energy (the magnetic flux) is being maintained kinetically by the current, yet it can correctly be considered as the true potential energy of the circuit. If now in the Ampere trough, Fig. 13, the bridge piece is originally at *A* and is permitted to move by itself to *B*, it is true that the potential energy (approximately proportional to the areas of the loops) will have been increased thereby, but this does not contradict the general law any more than in the above

water analogy. While A was moving to B a counter e.m.f. was being induced due to the creation of the new flux in the lengthened parts of the circuit L L; this temporarily reduced the current by opposing the direct e.m.f. (a constant potential source being assumed) and therefore temporarily the potential energy (the flux) is reduced by an amount equal to the kinetic energy consumed in moving the bridge A; momentarily therefore the original potential energy is reduced by a conversion of a part of it into kinetic energy, precisely as in the water tank analogy.

But when the motion ceases, the counter e.m.f. also ceases, and the current again rises to its original amount, it being assumed of

FIG. 13.



course that the added resistance of the increased length L L is negligible as compared with that of the rest of the circuit. In this building up again to its original amount, the current has thereby supplied the additional potential energy of the lengthened circuit, and this additional energy will of course be exactly equal to that which would be required to start an equal current in the added parts L L, that is, to overcome the self-inductance of those parts; this energy is supplied by the source and not by the original potential energy. The fact that the final potential energy may be greater than the original, therefore does not contradict the general law of mechanics as applied to electric circuits any more than it did in the above mechanical analogy. The confusion is due to the fact that (like in the water analogy) a true potential energy is being maintained kinetically by a source which may add new potential energy to the system. The true *cause* of the motion of a circuit is still in accordance with this general law of mechanics.

The writer believes his statement is incontestable that in the case of electric circuits the self-conversion of the potential energy (flux) into kinetic (mechanical movement) is and must be charac-

terized by the production of a counter e.m.f. by that motion. Hence he believes that it is a general law that a current-carrying circuit will tend to produce *any* and *only* such motions of its conductors as will produce a counter e.m.f. somewhere in that circuit, though as explained above, not necessarily in the moving part itself.

In the particular experiment described by Maxwell, on which he based his generalized statement that no axial force can exist, an axial motion could not have produced any counter e.m.f., hence should not have existed according to the present writer's statement; but in other forms of experiments, as in some of those described above, in which an axial movement can produce a counter e.m.f., the existence of the axial force is evidenced.

A thorough experimental analysis of the various forces which act in those electric furnaces (like those in Fig. 9), and which gave rise to much of this discussion, is very difficult, as the current densities are very high and the heating is very great, enough to vaporize mercury very quickly and to melt solid conductors. Moreover the results are very apt to be masked by forces foreign to the one being studied. The position of the leads also is likely to affect the results and perhaps greatly; it is known that the pinch effect is very greatly affected by neighboring currents or magnetic bodies like the iron of which the electrodes were made. It is also possible that the Hall effect (variously defined) may become formidable enough to be involved. Alternating currents were used, and some of the results might be different for direct currents.

Concerning forces caused by magnetic flux, attention should also be called to the fact that the density or intensity, as distinguished from the amount of flux, may determine the resulting force on a conductor. In the case of a liquid couductor in a channel which turns a corner, the forces caused by the flux will be quite different on the inside of the corner where the flux is denser than on the outside where it is far less dense. Similarly, when a relatively small channel containing a liquid conductor discharges into a large bath of conducting metal, as in some furnaces, one must expect that any forces due to the flux, may change abruptly at that point. In the case of a current-carrying conductor leading vertically into the ocean, there would be very decided magnetic forces around the conductor, but none that are perceptible in or above the ocean; the magnetic effects then act as though they were dispersed.

In an air gap of a magnetic circuit the lower pole of which was large while the upper one was sharply pointed, the writer found that a fragment of iron resting on and held by the lower pole would be lifted up to the upper one, where the same field was denser.

It is hoped that the facts and suggestions given above which were brought to light by these high-current density phenomena, will encourage further research and discussion among those best able to study the subject. At these very high-current densities forces become formidable which under ordinary conditions were too small to be noticed.

PHILADELPHIA,
MARCH 14, 1921.

Pure Platinum.—According to EDWARD WICHERS, of the Bureau of Standards (*Jour. Am. Chem. Soc.*, 1921, xliii, 1268–1273), platinum of a high degree of purity may be obtained by repeated precipitation as ammonium chloroplatinate; four such precipitations are usually sufficient. Each precipitate is washed two or three times by suspension in a rather large volume of a solution of ammonium chloride containing from 15 to 20 per cent. of that salt. The washed precipitate is collected on a filter, dried, and ignited to platinum sponge in an electrically heated muffle furnace. The sponge is converted into hydrochloroplatinic acid by means of aqua regia; and the entire cycle of operations is repeated. The final ignition is made in a porcelain dish, in an atmosphere of hydrogen; the dish is covered with a silica plate, and heat is supplied by a gas flame.

The sponge was melted to a button on lime by means of the oxyhydrogen flame. Platinum with a minimum calcium content was obtained when a considerable excess of oxygen was present in the flame. Apparently, if the flame contains insufficient oxygen, lime is reduced to metallic calcium which passes into the platinum. When the fusion on lime was made in an electric induction furnace, contamination of the platinum by calcium did not occur to any appreciable extent. When platinum was fused in an induction furnace, which was lined with magnesia, with or without magnesium fluoride as a binder, the platinum was contaminated with as much as 3 per cent. of magnesium, possibly as a result of the dissociation of the magnesia at the temperature of the furnace.

By this technic platinum has been obtained with a calcium content probably not in excess of 0.0001 per cent.

J. S. H.

GEOLOGY IN PARTNERSHIP WITH AMERICAN INDUSTRY.*

BY

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Director, U. S. Geological Survey, Department of the Interior, Washington, D. C.

TWENTY-FIVE years ago the college student was fairly certain in making his choice of a life-work between science and business. Then the dividing lines were fairly distinct between a life of quiet study in a search for truth and a life of strenuous activity in a struggle for wealth; now much of that distinction has been lost, for we find science and business working together and the scientist even earning a salary comparable with that once thought of only as the compensation of the merchant prince or the captain of industry. It is because of these changed conditions that I have followed the thought of Editor Rickard, of the *Mining and Scientific Press*, that the geologist "has developed from the academic student of Lyell's and Murchison's time to a pioneer of commerce; he has been required to submit his work to the test of economic usefulness, and he has succeeded triumphantly; he has become a real partner to the engineer and to the capitalist, and they appreciate his comradeship." With that thought in mind I will discuss with you the partnership of geology with industry.

Science of all kinds has become more practical; whether we who chose science as a shrine at which to worship like it or not, science has become a centre of service. This utilitarian trend of science has logically brought it into close touch with industry, and the scientist can now claim partnership with the industrial executive.

The linking of scientific research with industrial practice has in recent years found definite expression in the system of industrial fellowships. The latest administrative report of such an industrial experiment-station in your own State lists nearly fifty of these fellowships, and I was interested to note that nearly one-fourth of the subjects under investigation are connected with the utilization of mineral products. This is a very practical kind of partnership between science and industry, and the fact that industrial corpora-

* Presented at a meeting of the Mining and Metallurgical Section held Thursday, April 7, 1921.

tions and associations of manufacturers are investing increasing amounts in technical research under truly scientific auspices is proof enough that the partnership has profits to divide. Although it may seem to have been long delayed, recognition of the practical value of theory is now widespread.

In referring to this delay, however, I am not forgetful of the occasional flashes of such recognition far back in our history. Indeed, the very name of this Institute recalls that pioneer American in whom an interest in science and a knowledge of practical affairs were so happily blended, that unique citizen, Benjamin Franklin, who was at once a leader in scientific thought and economic writing, a competent business man at home, and a brilliant diplomat abroad. Citizenship of that type is never out of date.

Geology was never a closet science: its subject is this earth of ours, and its field is all-out-of-doors. The horizon of the geologist is wide, and his contacts with life are many, so that geology has most naturally come into touch with human needs and by that association has become more and more practical. Yet for a long time geology was preëminently an amateur study: any reviewer of the contributions to geologic science would give a large share of credit and honor to students who can not be considered professional geologists. In geology, as in other branches of science, the only compensation offered to many of the leaders was their recognition by other scholars, and sometimes not much of that. Even here in America in more recent times only a few positions have been available for geologists, either as teachers in the larger colleges or as investigators on state or federal surveys.

Only as the utilitarian value of geology has become recognized has a use been found for geologists. Forty-odd years ago, in a congressional debate, the practical functions of geology were specified as to "prevent the waste of natural resources, clear the way of progress, and promote the triumphs of civilization." Those specifications might be rewritten in plainer language to-day, but even in those well-rounded phrases the task of the geologist is happily stated. To discover and measure the resources of the earth and to show how they may be utilized is a very practical part to play in this world of work.

The professional geologist is very much a modern product; indeed, it has been given to us of this generation to see geology establish itself as a partner of business. It was in the last fifty

years or so, that geologic principles and methods were first applied in a professional way to the hunt for oil, and only in the last twenty years has oil geology become essential to the oil industry. Within a single decade the number of petroleum geologists in consulting practice increased from two or three to several score, and in addition geological staffs have been built up by the oil companies themselves. To-day the most thriving of geological societies the world over is the American Association of Petroleum Geologists, which has more than 600 members and maintains a high professional standard of membership. So large a growth of a single branch of a profession is hardly possible except as it springs from service rendered.

This rapid expansion of the field of oil geology, like the mushroom growth of the oil industry itself, has attracted wide attention, yet the principles of petroleum geology are thoroughly scientific, and the petroleum geologist is not the only type of geologist who is in demand for practical service.

Science and industry in their present-day progress are treading paths that converge, until they are now well within each other's sphere of influence. Science is becoming more useful, and industry is becoming more efficient, and this mutual approach means a mutual attraction. I may illustrate this by pointing to the gratifying tendency of up-to-date constructing engineers to consult geologists upon questions related to large engineering projects. To the trained geologist, familiar with the many kinds of rocks and their varied habits of assembling, it has seemed strange indeed that so many engineers have gone ahead with great works of construction on the theory that rock is rock and that nothing can be learned of the third dimension of the earth's crust in advance of actual excavation. Possibly, however, some of this blame for their neglect of the geologist may be laid at our own door, for all of us do not seem to be firm believers in the practical value of our own science, and only in these later years have we learned to talk of the facts of geology with any approach to the quantitative exactness that the engineer requires.

The standing of science in the world of affairs has been greatly changed in recent years. As Doctor Little says: "The war has at last placed science above the salt, even at bankers' dinners," and we can also claim for geology what he says of his own science: "Chemistry is saluted by the man on the street."

We may take as a sign of the times a recent editorial in a leading newspaper of the South, in which this changed attitude is mentioned, "condescension or indifference, if not hostility," giving place to recognition that to such patient seekers after facts as the chemist and the geologist are we "chiefly indebted for material progress and ever-widening opportunities." That editorial utterance is a gratifying tribute to the scientific worker "who explores matter that he may capture it and coerce it into human service."

That the geologist has won a high place in the world is gratifying, but that place carries a corresponding degree of responsibility, and we may profitably review the steps that have led up to it and see what are the requirements of service imposed on the present-day professional geologist.

The demand for industrial geologists or geologic engineers is not altogether of recent origin, for the search for raw materials is not new. The earlier geological surveys aimed in a somewhat indefinite way at the development of resources, but immediately after the Civil War geologic exploration took on more of a professional character and connected itself with railroad building. Then began the hunt for traffic business through mineral discovery and mine development. The scientific investigation of the economic resources of the New West was systematically undertaken, and some of the traditions of these pioneer surveys have continued to our day. The development of our material resources was then, as now, recognized as a problem demanding scientific research, and the philosophy of the industrial conquest of a continent was clearly set forth forty years ago by Clarence King in his plans for the future of the United States Geological Survey. Director King then stated that without full scientific knowledge of all the elements of national wealth—especially the mineral commodities and products—commerce is mere transportation, industry is short-lived, and the economic equilibrium of population with local resources is not to be attained. To promote the progress of industry was even then the self-appointed task of geology.

The two basic productive industries, agriculture and mining, have long been served by geology, and this close relationship was most keenly realized during the World War, when food and munition requirements demanded in turn new sources of fertilizers and other raw materials. Thrown as we were upon our own resources

as never before since Colonial days, we had to recognize the geologist as a partner in our industrial expansion who could not be spared, however strong might be his personal preference for overseas service. The raw-materials problem was one we had to solve to meet the exigency, and now that the exigency is happily past we find ourselves studying our material resources with a new and broader outlook. A specialized type of geology is now demanded—the application of geology in terms of commerce; and to be most useful geology must occupy conjointly with industry the whole field of commerce, which is the whole world.

The dominant position of the United States in its supply of most of the essential minerals is only the starting-point in commercial geology: the worker in applied science of this type must interpret his facts of ore occurrence in terms of use and of value to mankind. The geologist or mining engineer who examines a Nevada ore deposit must bring to his task an eye trained to see far beyond the Basin Ranges that form his actual horizon: his experience and his store of information must endow him with the power to take the international view of mineral resources and of the industry and commerce that are founded on them. At this desert prospect the geologist must not only see the ore minerals as they occur here, deposited and enriched by the processes of nature, but must compare the quality and quantity of the unmined ore here with the similar facts of nature that give value to the ores in other districts, whether in Peru or in distant Burma. It is not simply the geologic problem of metallic minerals outcropping on a Nevada mountain side, for the geologist's vision must include also the industrial and commercial problems of the smelted ore and refined metal on their way to the markets of the world. In terms of commercial geology ore deposits take on competitive relations, which depend in turn upon the geographic facts of distribution—not only the location of this or that body of ore, but its distance from the supplies of fuels, power, and labor required to win the metal from the ore, and finally the distribution of the markets where the metal can be put into the service of mankind.

Thus to broaden and extend the geological engineer's vision is not to commercialize his science, though it surely does make it more useful. The scientist may be obliged to translate some of his technical terms into the language of the market-place, but in this translation he will perceive that a larger duty has come to him—

the duty of interpreting the facts of his science in their relation to national life.

The United States Geological Survey has just issued the first volume of a World Atlas of Commercial Geology, a work planned for the desk of the business man as well as for that of the college student. This atlas exhibits graphically the distribution of mineral wealth over the entire surface of the earth, for one of the lessons we learned in the school of war was that it is not enough to know simply what America contains and possesses—we must know the mineral wealth of the world, exploited and unexploited, in all its continents and countries.

These facts, as disclosed in maps and text, sustain in part the patriotic pride we feel in our national primacy in mineral wealth; but they also no less plainly appeal to our patriotic regard for the future continuance of our present prosperity. To be adequate any stock-taking we now attempt must include world resources and world needs and by balancing production against consumption must set forth a true picture of world competition, for under the complex requirements of present-day life no continent, not even North America, can be self-sustaining. It is no longer enough for us to make an inventory of the mineral wealth of the United States: we must supplement that inventory by a broad understanding of world demand and supply.

The raw-material issue will last through the centuries; but unlike the foodstuffs, whether corn or cattle, or the fibres, whether cotton, wool, or pulp wood, the minerals, such as oil, coal, copper, or iron, have but one crop to harvest. The duty laid upon the geologist to discover every mineral deposit and to disclose its limits thus becomes more than a service rendered to his employer, the landowner or mine operator: it is a part of the national undertaking to determine the assets available for use by this and future generations.

The industrial resources of a nation are made up only in part of its supplies of raw material, for labor, power, technical ingenuity, managing skill, and capital are other constituents that enter into the composite reaction that we term industry; yet possibly that stage in world development has now been reached in which the present output of raw materials is fairly indicative of national rank in natural wealth. Undoubtedly this or that country is living far beyond its means in its annual output of this or that product of its

mines, and too soon its store of mineral treasure will be exhausted; on the other hand, some countries possess virgin resources that still await utilization. Thus the statistics of the mineral production of Europe and North America, which contain the workshops of the world, doubtless overemphasize the relative importance of these continents as future sources of mineral commodities compared with frontier continents like Africa and South America.

The practical value of this exhibit of the world's mineral assets is evident. Experience gained during the World War emphasizes the advantage of an adequate supply of raw materials close at hand, yet that there are certain economic limits to domestic independence in raw materials is clearly shown by the readjustments already made. The more facts we possess bearing upon the relative quantity and the relative availability of the mineral resources of our own and other countries the better able will be our captains of industry to decide whence they should derive their raw material. But the output of raw minerals measures only the first step in industry. The mines of the United States should be looked upon primarily as tributary to the many mills, shops, and factories in which the skilled labor of the country may find its opportunity for a livelihood. The production of crude oil, coal, pig iron, copper, or other raw minerals for export is surely less desirable than their production for home consumption. Then, too, both commerce and industry need not only exports but imports, and raw materials may well supply this need. Knowledge of what the whole world contains is plainly the best basis for discussing public policy and planning private business.

We need to realize that American industry has reached the intensive stage. Six years ago I had the privilege of discussing here in Philadelphia the distribution of industrial opportunities as affected by the distribution of raw materials. In December, 1914, we were just beginning to readjust some of our industries to the use of American substitutes for imported ores and other mineral products, but already there had been some gratifying returns on the scientific study, through many decades, of the distribution of mineral resources that had not before been needed. Bits of knowledge that had been merely interesting became highly valuable, or, as I then expressed it—"The dollar mark attached itself to these facts over night."

American business becomes more and more complex as by-

products and side lines are added to industry and commerce. These additions are sure signs of economic progress, but this expansion necessitates the employment of specialists. As Dr. J. T. Young pointed out fifteen years ago, when he was Director of the Wharton School of Finance and Commerce, this expansion of business broadens the field for the man of scientific training: the widening of the business horizon has created the need for men of broader vision. The larger the business undertaking the greater its need of a staff of technical advisers who can see markets and supplies in terms of a generation rather than of a fiscal year—men who can measure the unseen and weigh the undiscovered. In planning for the future we must reckon with possibilities and probabilities. So it is that many corporations other than mining companies now employ geologists. Raw-materials specialists are employed to hunt for the needed supplies, and I notice that one former associate of mine has been engaged by a glass company; another geologist has gone into the employ of a maker of lumber substitute, and still another is serving the needs of our largest by-product coke company.

I have mentioned the fact that geology has begun to meet the engineer's demand for exactness as well as the business man's demand for usefulness. You may ask how successfully the oil geologist, for instance, has met the test. It is true that hard-headed men of business, who formerly gave scant courtesy to science, now employ geologists, but with what result?

The first duty of the oil geologist is self-evident—to find the oil. To discover a resource that is so deeply hidden seems almost the trick of a magician, and the unscrupulous expert is willing enough to enshroud his acts in mystery. Yet oil geology is not magic, but simply common sense backed up with a large collection of carefully observed facts. The stimulating and strengthening element in the growth of oil geology has been the promptness of the test to which the geologist's judgments are subjected. The drill shows up the value of his science before he can shift responsibility. To convince a former chief of mine that the oil geologist is right more than half the time, I had a test made of the measure of agreement between the structure mapping and the results of the drill. The study covered a number of townships of the Osage lands, a region which perhaps favors the geologist more than some others, but care was taken to include townships in which the

geologic relations were not wholly plain as well as those where the structure had been worked out to the satisfaction of the geologist. A few productive wells were found near synclinal axes and some dry holes were found on anticlines, yet this impartial study showed that the geologist, when his work was tested by the drill, had been right 87 per cent. of the time. The public can ask of science no better percentage of successful achievement than that, and if the business of the country were conducted with the same degree of accuracy the high cost of living would be a less troublesome economic issue.

In its partnership with industry, geology can bring into service a special talent. The science of geology deals with earth elements not only in the mass but also in their setting in time. The geologist is truly fortunate in possessing this sense of time. With his eye trained to see far back into the earth's remote past, he is better fitted to put correct values upon the episodes of the brief present day in which we happen to live. Intellectually this long backward view gives him poise; practically this ability to see things in true perspective leads him to plan intelligently centuries ahead. This picture of the geologist as one who is gazing into the future with large practical foresight runs counter to the popular conception of him as one who is ever poring over the dusty records of the past, yet I believe the working geologist of to-day is really inspired with this purpose to do his part in insuring the continued welfare of his country. Prosperity will fail to satisfy us unless it is backed up with guaranties of permanence. Whatever we are to enjoy this year and next year we wish our children's children to enjoy in equal if not in larger measure. We ought to take out nation-wide insurance to cover this forward-looking wish, if we can.

So I believe it is especially true of the geologist that his training has made him look forward—he is concerned for the future of his country. As an engineer he examines the foundations of national greatness to see if they promise to stand the test of time, and his desire is to make them serve many days and generations. Thus the geologist thinks of American industry as founded on stores of energy and of raw material, and he studies the geography of industry—its sites and its markets—in terms of adequacy and permanence of resources. After our war experiences it was natural that the geologist should discuss the economic limits to domestic independence in minerals. There must be some economic limit to

this possible self-sufficiency, even in a country so wealthy in raw materials as our own. With the question of adequate supply, which was uppermost during the war, is now joined the question of satisfactory price, which regains its old-time prominence with the return of competitive conditions. Yet the pendulum of economic thought can not swing back to its former extreme: the truths learned during the war exercise a drag that ought to keep our thinking somewhat nearer the normal.

The first lesson we learned in the experience of meeting the insistent demands of a war program with its rapidly expanding industries was to think in terms of quantity of a commodity rather than of its cost. So while we can no longer afford to pay any price for immediate delivery we realize better that quantity is the truer measure of usefulness and that the totals stated in dollars may not express the advances in industrial growth they seem to show. We have lost some of our old-time faith in the dollar as a standard measure of value.

Connected with this emphasis upon tons rather than dollars in considering the mineral raw materials is the necessity of thinking in terms of low costs rather than in terms of high prices. The day of excess profits that came through over-high prices ought soon to pass, and the day of lower levels of both cost and price ought soon to dawn. The producer of raw materials, whether farmer or miner, surely deserves his share, but in discussing profits to owner or wages to worker the truth should never be overlooked that the market price of the mineral fuel or of the ore is but the starting-point of some other industry, and only disaster can result from keeping a price too high. The rôle of the mineral industry is not to exploit markets but to supply consumers.

Industrial expansion on the scale imposed upon our country as its part in the war also cleared our judgment as to value in terms of utility. Gold was not one of the "war minerals," the increased output of which engaged the best efforts of geologist, metallurgist, and mine worker. Gold may have had its place in the war chests of militaristic nations, and it continues to hold its place as the universal measure of value, but gold is not a raw material whose general utility is at all comparable with that of its more democratic fellows like iron or copper. Indeed, there is some reason to liken this "noble metal," which has so long held the allegiance of mankind, to the idle aristocracy of Europe and to

suggest that the more abundant the world's supply of gold the poorer off we are in the humble but useful things of life. It is a nation's output of coal and iron, petroleum and copper, sulphur and lead, cement and zinc, brick and aluminum, that gives it power, rather than its output of gold and diamonds. The war-time effort to rescue platinum from its associations with luxury and idleness and draft it into the service of war industries was a tardy public recognition of the fact that this precious metal is also highly useful.

I have already referred to the dominance of the United States in so many of the essential minerals. A simple comparison of the statistics of production and consumption in different countries is enough to prove that America is in the highest degree self-sufficient. In the five essential mineral raw materials coal, iron, copper, lead, and zinc, for example, the United States in 1913 showed an aggregate exportable surplus of 24 per cent., whereas Germany's deficiencies in these same essential minerals amounted to 40 per cent. Such facts at least suggest that America can be progressive and generous for the same reason that Germany was tricky and relentless.

The geologist's best contribution to industry is perhaps his advice regarding the future; he believes in the future prosperity of his partner, but feels the need of planning for it. Resources are expendable, but industry is long-lived. The geologist believes that he sees plain facts spread over the face of this old earth as well as through the pages of history, and he is keen to safeguard the future security of the American industrial program. The bounty of Nature has bred into our American life that type of optimism that thinks too little of the morrow. To offset this blind faith in future security, the geologist has had to be the first to utter the note of warning that the oil supply is not unlimited—and indeed our vast stores of coal are not so distributed that thrift in the use of coal is an unnecessary national virtue. The geologist accepts his responsibility for increasing the accuracy of the inventory of the country's natural assets and for bringing home to the people a full realization of the future value of these expendable resources. It is in view of these opportunities of the geologist to help make safe the future of the country that I have come to think of geology as a phase of citizenship rather than as merely a branch of science.

In any articles of copartnership that may be drawn up between geology and industry there should be full recognition of the radical difference between the character of the work of the partners; the stop-watch can not be held on science, nor can the line of research be rigidly plotted—short cuts in science are not to be relied upon.

Partnership understandings between science and industry should provide for credit for by-products. Research may fail to deliver the results sought and yet may uncover a side line of even greater value. The advantage of the scientific method of collecting facts and deducing principles is that the facts and principles thus acquired have their own value; and this may mean their usefulness for some other purpose even if the immediate result is negative. The geologist who returns with an adverse report on an oil lease may have worked out criteria by which he later, and in another county, discovers a new oil pool.

The geologist on his side owes it to his prosaic partner, who thinks in terms of results, to see that no esoteric glamour is thrown over his methods of investigation. True science is not magic, and there is so much of common sense in what we term geology that whatever we really know can usually be explained in plain English. Ultratechnical language may camouflage hazy thoughts; and though scientific terms have a proper function in labeling our properly arranged collections of exact facts, such terms neither describe nor explain the truths of nature. The practical man of business is warranted in not giving too much credit to the geologist who can not tell his story in common language, and the world should be especially suspicious of those of us who persist in concealing our thoughts or lack of thoughts under a protective cover of professional jargon. The most valued commendation I ever received was given to me by a well-known captain of industry in his comment that I had told him things he ought to know in words that he could understand.

Another phase in this partnership between science and industry partakes more of the personal relationship, and that is the taking over into the business world of scientific ideals and scientific standards. Here is something that may be termed a professional obligation of the geologist—the recognition of our science in the market place counts for little unless we see the opportunity for our science to coöperate in the raising higher of our business ideals. A

geologist can have no double standard—one to guide his research work in pure science, the other to measure off his answer to a practical question. The same exact method, the same fair judgment, and the same fearless decision must mark his activity in the world of work as in the world of study.

There is not even yet the widespread respect for specialized science that would seem to be warranted by the type of its service. A better understanding of the task of the specialist, of his training and his methods of investigation, is needed to give effectiveness to his work on some practical problem. The popular idea that a professor could be put at almost any job received the stamp of governmental approval during the war, when splendidly equipped specialists were ordered to show their genius in learning the tricks of another trade, and when work in their own lines was assigned to specialists in others. In terms of shop management and industrial efficiency the Washington method was most wasteful, yet I fear that it only reflected the popular ignorance regarding specialized science.

Geology is distinctly a specialized science, and as such it can render its own special service to industry. I have outlined the part played by geology in our national development, and I have suggested, I trust, the larger share that this branch of science can have in helping industry win for us a greater national prosperity. But the popular appreciation of the scientific aid rendered in the utilization of these resources is still far from adequate. This is the human side of so material a subject as mineral resources. I know the scientific worker's intense devotion to the public service, and I crave for him the larger recognition that is his due. The geologist can help in the world's work and he wants to help more.

Atomic Weight of Zinc.—GREGORY PAUL BAXTER and JAMES HALLETT HODGES, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1242–1251), prepared pure anhydrous zinc chloride by the action of a current of dry chlorine gas upon anhydrous zinc bromide. They then analyzed this zinc chloride in aqueous solution by means of the electric current, using a mercury cathode for deposition of the zinc. Their results showed 47.970 per cent. of zinc to be present in the zinc chloride; hence the atomic weight of zinc is 65.38.

J. S. H.

Cistern Filters not Germ-proof. (*U. S. Geological Survey Press Bulletin No. 478*, October, 1921.)—Cistern water that is used for drinking should be gathered with great care. Properly constructed cisterns that receive rain water from roofs generally afford good drinking water, but water of doubtful quality that is stored in cisterns is of course not safe for domestic use. According to the Survey most of the filters that are used in connection with cisterns do not remove the germs of disease, though they may make the water clear and apparently safe. Many cisterns are divided into two compartments by a brick wall, the water being admitted into one compartment and pumped or drawn from the other after it has passed through the wall. The passage of the water through the brick improves it in clearness and color, but not generally in sanitary quality.

A Study of Frary Metal—Calcium-Barium-Lead Alloy.—The importance of this alloy lies in the fact that the shortage of antimony at the beginning of the war led to investigations for substitutes, especially in the manufacture of shrapnel bullets. Frary and Temple procured patents for alloys of barium and calcium with lead. Owing to the increased use of gas shells, the demand for shrapnel fell off, but the alloy was found to have practical value as a bearing metal. The Bureau of Standards reported favorably on it, having obtained better results than with standard babbitt. The alloy is now made on the large scale. Cowan, Simpkins and Hiers, of the research laboratory of the National Lead Company, have made studies of the alloy as produced electrolytically, and give the results of this study in a paper presented at the fortieth meeting of the American Electrochemical Society. The procedure of manufacture consists essentially of placing mixed calcium and barium chlorides upon a mass of high-grade pig lead in the molten state. Each pot is provided with an adjustable graphite anode. The anode is first immersed in the chloride mixture and the current turned on. The resistance is sufficient to melt the mass, when the calcium and barium set free are absorbed by the melted lead. (Compare, in this connection, the note concerning lead-sodium alloys, in this journal for October, 1921, p. 452.) The operation is conducted until the proper amounts of calcium and barium are introduced into the lead the fact being ascertained by occasional testing of samples. The alloy thus produced is essentially a ternary alloy, containing up to 2 per cent. barium and 1 per cent. of calcium. Small amounts of mercury may be added. Equilibrium diagrams and metallographic views are given.

H. L.

A PHOTOMICROGRAPHIC METHOD FOR THE DETERMINATION OF PARTICLE SIZE OF PAINT AND RUBBER PIGMENTS.* †

BY

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WHEN a biologist desires to measure the diameter of a tissue cell or the length of a bacterium he may use for his purpose a filar micrometer eyepiece calibrated by means of a stage micrometer. Aside from a certain amount of facility required for the manipulation of this instrument his task is a comparatively easy one. Objects like cells, etc., possess, as a rule, a high degree of uniformity with the consequence that a fairly accurate average diameter may be obtained with relatively few measurements. Further than this it is not a vital issue with the biologist if his average measurement, so obtained, happens to deviate from the most probable value by the apparently insignificant amount of one- or two-tenths microns.

On the other hand, the microscopist who wishes to determine the average particle size of a paint or rubber pigment has a problem to deal with which, in a sense, is diametrically opposite to the case just cited. Here, even in the most uniform pigments, will be found particles ranging from the nearly or quite ultramicroscopic to those with a diameter many times as great. Hence, it sometimes becomes necessary to measure thousands of particles, if a high degree of accuracy is required, in order to obtain a value that closely approximates the true average. To try to accomplish this with a filar micrometer would not only consume an unwarranted amount of time but the process itself would become so tedious that it would discourage, at the start, anyone who attempted to solve the problem in this manner.

Then again, the matter of accuracy assumes here a truly important rôle. A few years ago the technical advisor who would

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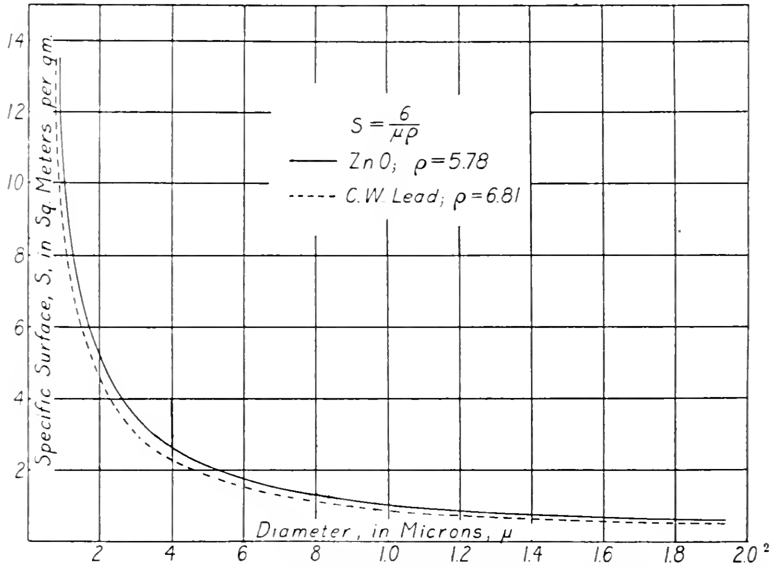
* Communicated by the Author.

† The expression "Particle Size" is used in reference to diameters, as customary amongst paint and rubber technologists.

condemn a consignment of pigment on a matter of one-or two-tenths microns (if he were able to detect it) would have been considered hypercritical to say the least. But let us see if such a hasty conclusion arrived at without due consideration, is justifiable or not.

The character and behavior of fine pigments depends to a large extent on the magnitude of their specific surface.[1] Assuming the particles to be spheres, simply for the sake of simplicity—

FIG. 1.



Curves for zinc oxide and corroded white lead, showing relationship between specific surface and diameter of particle.

and this assumption cannot fundamentally alter the argument—it can be shown that,

$$\rho S \mu = 6 \qquad \text{(I)}$$

where, $\rho \doteq$ density of material.
$S =$ specific surface (square metres per gram of material).
$\mu =$ diameter of particle in microns.

[1] Specific surface is inversely proportional to the "diameter" of the particle or to "particle size." Such qualities of a pigment as tint, brightness, hiding power, and oil absorption, in paints, and resistance offered to abrasion in rubber are functions of particle size. It would be a great mistake, however, to assume that these qualities depended *entirely* on particle size. Other factors enter in, such an index of refraction, density, color, forces of adhesion and surface tension.

[2] If μ is the harmonic mean of the three dimensions, then this equation will hold for any rectangular parallelopiped. Pigment particles roughly approximate this form and that of spheres.

Plotting the equation for zinc oxide ($\rho = 5.78$) and lead carbonate ($\rho = 6.81$) gives the two curves illustrated in Fig. 1. It should be noted that when the pigments are comparatively coarse, from $.8\mu$ in diameter upward, a difference of $.1\mu$ or $.2\mu$ has but little effect on the magnitude of the specific surface. From $.8\mu$ downward, however, the reverse of this condition becomes true. In the case of very fine pigments such as zinc oxide it will be found possible to purchase on the market various grades of material some of which will measure $.6\mu$ and others only $.3\mu$—a total range of but $.3\mu$, yet one sufficiently great to cause a difference of 100 per cent. in the specific surface. Studying the situation from this point of view will show that the investigator who considers the importance of one- or two-tenths microns is not so fastidious after all.

As a matter of fact the author feels no hesitancy in predicting that within the next few years the manufacturer of fine pigments who wishes to maintain his position in a keenly competitive field will find it necessary not only to become acquainted with the particle size of his products to the first, but even to the second, and probably the third, decimal place in microns.

THE METHOD.

The fundamental idea involved in the method is by no means a new one. In all probability it has been employed many times by various investigators and for numerous purposes; yet the author is not aware of a single case where it has been sufficiently developed in detail so as to make it of practical importance in the special line of work to which it is here applied.[3]

Briefly stated, the pigment is prepared in such a manner so that a photomicrograph, at a known magnification, can be taken, showing *clearly and distinctly the individual particles,* which are then measured from the negative by a method to be described presently.

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[3] The method of grain measurement exployed by metallographers is fundamentally similar to the photomicrographic method of particle measurement. Note on grain size, by G. H. Gulliver, *J. Inst. of Met.,* 1918.

"The Determination of Grain Size in Metals," by Zay Jefferies, A. H. Kline, and E. B. Zimmer, *Trans. Am. Inst. Mining Engineers,* 1917.

PREPARATION OF THE SAMPLE FOR PHOTOGRAPHING.

About a milligram of the pigment is placed on the centre of a microscope slide to which is added a drop of redistilled turpentine. The slide is to be held at the two ends between the thumb and first finger; a glass rod, with smooth, straight sides, so that it will come in close contact with the glass, is now used to disperse and rub out into an extremely thin layer the material in the turpentine. This is best accomplished by a forward and backward motion of the rod in the direction of the length of the slide and extending over the central area only. The rubbing must cease at a certain critical stage, when there still remains sufficient turpentine unevaporated to prevent the mount becoming "streaky," and yet not enough to float the particles which would allow them to flocculate. By a slightly upward flourish of the rod on the last stroke the mount can be made wedge shape, that is, dense in one part and thin in another, with all intermediate grades of density between. In this way it becomes possible to select a section for photographing that will show neither too many particles nor too few per given unit area.[4]

The next step, after the material is properly dispersed, is to completely remove the remaining turpentine. This should be done by laying the slide on a hot plate, the temperature of which is sufficiently high to cause evaporation within forty or fifty seconds Care must be taken that volatilization is complete. This is satisfactorily ascertained by noticing if any odor of turpentine remains after heating. The particles will now be found to be cemented to the glass and should remain in this condition, if a reasonable amount of care is exercised in handling the slide. When suffi-

[4] This method of dispersing the particles is to be used principally with the finest pigments, such as zinc oxide, lithopone, white lead, etc. In the case of these materials it will be found impossible to produce any *grinding* effect that will cause the *individual* grains to be broken up into smaller ones. This is on account of the fact that neither the glass slide nor the rod are optically flat, and consequently they are unable to come in close contact with each other except at a very few points.

With coarser materials such as clays, barytes, asbestine, etc. (which will probably feel gritty), only the slightest possible pressure must be brought to bear upon them with the dispersing rod for here there is some danger of a real grinding effect becoming manifest. Fortunately, these materials are so large that flocculation does not prevent the outline of the particles from being seen and a measurement made, hence, very little rubbing is necessary.

ciently cooled a small drop of glycerine is placed on the centre of the mount and then covered with a thin slip. The excess glycerine must be carefully squeezed out at the sides of the cover glass and absorbed by filter paper. The mount is finished in the usual manner with a ring of Brunswick black.

If the above instructions have been properly carried out, and the mount now held to the light, the pigment, if its index of refraction is high, will just be perceptible as a faint cloud; if its refractive index is low, the pigment will be entirely invisible, except with a microscope.

Upon microscopic observation three essential conditions should be manifest. They are—

1. The particles will be in one plane.
2. They will be free from Brownian motion.
3. They will be dispersed, showing individual grains instead of aggregates and flocculates. (Compare Figs. 8, 9, 10 and 12 with Fig. 7.)

THE PHOTOGRAPHY.

It is not the purpose of the present paper to describe the method of using a photomicrographic apparatus. It is also hardly necessary to add that unless one has acquired considerable facility in the manipulation of such apparatus it would not pay to attempt its application in the measurement of particle size.

In regard to the present problem, however, it must be stated that all photographs are made with transmitted light, and that this light is to be absolutely axial. Obliquity of illumination will give a distorted image, causing an appreciable error in the results.

The beginner will find it advantageous to start with a fine-grained contrast plate, using hydroquinone developer. After he has obtained experience in handling these materials successfully, he should then try his ability with panchromatic plates and develop with pyro. There are plates of this kind made especially for photomicroscopy which give great detail together with sufficient contrast.

THE MAGNIFICATION.

Generally, in photomicrographic work, definition of structure is the one essential quality most desired. However, as the structure of a pigment particle will give us no information in regard to its size, the factor, definition, may be neglected here to a

certain limited extent.[5] On account of this fact it has been found an advantage to employ a magnification which otherwise would be too high if the best definition is to be obtained. Nevertheless, care must be taken that the photographic image of the particle gives edges sharply enough defined so as to make a satisfactory measurement possible.

With a 2 mm. apochromatic objective a magnification of 1500 diameters will be most convenient for pigments such as zinc oxide, lithopone, red oxide of iron, sublimed white lead, corroded white lead, Mathewson white lead, etc. Lower magnifications are used, naturally, with coarser materials. The method of measuring magnification is given under the section entitled "Errors."

MEASUREMENTS.

As previously pointed out, it sometimes becomes necessary to measure a thousand or more particles in order to obtain a sufficiently accurate average diameter. This demands a rapid method of measurement, if the work is not to become too irksome. The method is as follows: The negative, which must show from 200 to 250 distinct particles, is placed in a stereopticon and an image of it thrown on a screen, so situated that the total magnification of the original particle will be from 20,000 to 25,000 diameters. The image of the particles is measured with a millimetre rule. Particles which are out of focus to any extent at all, as the case will be with those around the border of the negative, must be neglected. In order to eliminate the possibility of duplication and skipping, the area of the screen is divided into small squares.

It is neither necessary nor desirable to consume time in estimating the fractional part of millimetres. These small errors are just as liable to be positive as negative, and it is reasonable to believe that their sum approaches zero as the number of measurements increases.

The length of time required for the measurement of a single particle should be approximately two seconds. As the readings are called off an assistant may take them down on an adding machine regulated to record number of items, so that by the time the measurements are finished their average can be determined directly.

[5] But to no greater extent than is shown in the photomicrographs, Figs. 8 to 13.

If the probable error and the uniformity coefficient are desired, a permanent record of each particle is made by the method

FIG. 2.

Particle Measurement Record Sheet

Millimeters. m.m.	12-17-20 Zinc Oxide #3B 1st	Frequency, f.	fxmm	v	v^2	$f \times v^2$ (Σv^2)
1						
2						
3						
4						
5						
6	卌 III	8	48	4.44	19.71	157.68
7	卌 I	6	42	3.44	11.83	70.98
8	卌 卌 卌 IIII	19	152	2.44	5.95	113.05
9	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 III	53	477	1.44	2.07	109.71
10	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 II	82	820	.44	.19	15.58
11	卌 卌 卌 卌 卌 卌 卌 卌 卌 I	46	506	.56	.31	14.26
12	卌 卌 卌 卌 卌 卌 IIII	34	408	1.56	2.43	82.62
13	卌 卌 II	12	156	2.56	6.55	78.60
14	卌	5	70	3.56	12.67	63.35
15	II	2	30	4.56	20.79	41.58
16	II	2	32	5.56	30.91	30.90
17	I	1	17	6.56	43.03	43.03
18	I	1	18	7.56	57.15	57.15
19	I	1	19	8.56	73.27	73.27
20	I	1	20	9.56	91.39	91.39
21	I	1	21	10.56	112.40	112.40
22	I	1	22	11.56	134.60	134.60
23	I	1	23	12.56	158.80	158.80
		276	2881			1449

Magnification, 20,000 diameters.

$$\text{Average particle size} = \frac{2881}{276} \div 20{,}000 = 0.522\ \mu$$

$$P_{A_D} = \pm .6745 \sqrt{\frac{1449}{276 \times 275}} = \pm .093$$

$$P_A = \pm .005\mu$$

Total probable error by Eq. XI, 1.37 %

$$\text{Coefficient of Uniformity, } U = \sqrt{\frac{276}{2 \times 1449}} = .309$$

employed in Fig. 2. The illustration is self-explanatory. Each stroke corresponds to a particle. The first column gives its measurement in millimetres at 20,000 diameters.

THE AVERAGE DIAMETER.

It is not always an easy question to decide which direction through the particle is its most representative "diameter." In measuring particles which approximate spheres in form, the best rule is to take only the horizontal direction. As the pigment grains will be orientated in every possible way on the screen, an average thus obtained will be, from a large number of measurements, not only the diameter of the average particle, but also the "average diameter" of this most representative particle.[6]

In the case of pigments composed of needle-shaped crystals, it is necessary to calculate the harmonic mean of the three dimensions of each particle. The negative, of course, is able to show only the length and width, and therefore the third dimension must be estimated. Fortunately most acicular crystals encountered in practice are either tetragonal or hexagonal and so the third dimension will be equal to the smaller of the two measurable ones. The average diameter will be the average of the harmonic means.

ERRORS.

The result of a series of measurements, giving an average particle size, will be of little value unless it is known just how much reliability may be placed upon it. In order to ascertain this, it is necessary to make a complete study of the various errors encountered throughout the process. These errors are given in Table I; and below are subjoined comments upon those requiring explanation.[7]

---

[6] If the average particle volume is desired to be known it is necessary to base calculation on some assumption as to the shape of the particles. It is usually customary to assume that they are spherical in form. It should be noted, however, that by this method of particle measurement it is not necessary to fall into the error of using the *cubed average diameter* in place of the *average of the cubed diameters.* In order to avoid this mistake it is only necessary to replace the column f x mm. in Fig. 2, by f x mm^3. If the work is made systematic and a table of cubes is employed no insurmountable difficulties should be encountered in doing this.

[7] It is not to be inferred from the above statement that Table I includes *every* existing source of error. Manifestly it would be impossible to create such a table. It is believed, however, that this section omits no source of error which it is reasonably possible to study. Consequently it must be emphasized that where the expression *total error* is used, it is "total" only insofar as it includes the errors listed above.

TABLE I.

Errors and Mistakes Encountered in the Photomicrographic Method for Determining Particle Size.

(I) Errors in Magnification.	1. Calibration of stage micrometer. 2. Measurement of image of micrometer on glass focusing screen. 3. Measurement of bellow's length. 4. Determination of the stereopticon magnification (a. The ruled lines; b. image on screen). 5. Distortion of image on focusing screen.
(II) Errors in Obtaining Average Diameter of Particle Aside from Errors in Magnification.	1. Errors due to the fact that the number of measurements cannot be infinitely great. 2. Errors from disregarding fractional parts of millimeters in measuring image of particle. 3. Errors arising from the fact that the largest particles do not always occur with the proper frequency on a single negative showing but 200–300 particles. 4. Errors from poor judgment in selecting representative section for photographing. 5. Errors from diffraction effects, when particles, the diameters of which are less that the resolving power of the objective are photographed. 6. Errors due to distortion of the photographic emulsion, upon drying.
(III) Negligible Errors.	1. Errors in the ruling of the millimeter scale for determining bellow's length. 2. Errors in the ruling of the scale used in measuring the image of the stage micrometer. 3. Errors in the comparator.
(IV) Mistakes.	1. Poor focusing. 2. Oblique illumination. 3. Insufficient and excessive illuminations. 4. Underdevelopment and overdevelopment of negatives.

(I) 1, 2, 3. The magnification of the microscope is determined in the usual manner with a calibrated stage micrometer.

Instead, however, of using but a single determination, a number of such are made at various bellow's lengths.

Taking as the bellow's length, B. L., the distance between the smallest circle of light projected by the microscope,[8] and the ground glass surface on which the image is ultimately focused, a linear relationship will exist between B. L. and the magnification of the microscope, D_m, so that,

$$\frac{D_m}{\text{B. L.}} = K \qquad \text{(constant)}$$

If, then, K should be known for any particular set of lenses, the magnification is easily determined from B. L. In calibrating the stage micrometer used in this work there was a probable error of 5.0 per cent. in the 0.01 mm., and 0.5 per cent. in the 0.10 mm. division. Obviously the larger divisions were the more desirable ones to use. Note carefully, however, the remarks given under "Distortion" in regard to the use of these large divisions.

Writing for D, $\frac{I}{.1000}$, where I is the length of the image on the focusing screen of the .1000 mm. division, we have

$$K = \frac{I}{\text{B.L.} \times .1000} \qquad \text{(II)}$$

If P is the probable error, then,

$$\left(\frac{P_K}{K}\right)^2 = \left(\frac{P_I}{I}\right)^2 + \left(\frac{P_{\text{B.L.}}}{\text{B. L.}}\right)^2 + \left(\frac{.0005}{.1000}\right)^2 \qquad \text{(III)}$$

Assuming, for the moment, that an actual error exists in the calibration of the micrometer, then its effect will be to produce a constant error in K, and consequently can in no way influence the "smoothness" of the D.–B. L. curve.

Therefore, only the slight inaccuracies in the measurements of I and B. L. will cause points to deviate from this curve.

By repeated experiment it was found that with no more elaborate apparatus than a thin-edged rule and a small hand lens, I could be determined to within 0.1 mm.; also, with suitable precaution the bellow's length could be measured to about $\pm$1.0 mm.

In view of these facts it is obvious that that part of the error in the magnification due to the inaccuracies in the measurements of I and B. L. must be quite small; hence, the probable error will

[8] The eye-point.

not be appreciably affected if each point on the D.–B. L. curve is given equal weight.

Granting this, then for n points on the curve, equation (III) may be written,

$$\left(\frac{P_K}{K}\right)^2 = \frac{1}{n}\left(\frac{P_I}{I}\right)^2 + \frac{1}{n}\left(\frac{P_{B.L.}}{B.L.}\right)^2 + \left(\frac{.0005}{.1000}\right)^2 \quad \text{(IV)}$$

Should n be as great as 10, then the first two terms on the right-hand side of the equation may be considered negligible for practical purposes, and the error in K becomes equal to the error in the calibration of the micrometer.

With a 2 mm. Zeiss apochromatic objective and a 6X compensating ocular, K was found to be $25.96 \pm .13$.

(I) 4. An easy method for determining the stereopticon magnification, and one used by the author, is to cut two fine parallel lines in the gelatin on a photographic plate, previously exposed to light and developed to a good density. Next measure the perpendicular distance between these lines with a comparator. By means of the stereopticon an image of the lines is now thrown on the screen and measured and the magnification, D_s, determined directly.

If R represents the distance between these rulings and the subscripts I and N refer, respectively, to image and negative, then,

$$D_S = \frac{R_I}{R_N} \quad \text{(V)}$$

and,

$$\left(\frac{P_{D_S}}{D_S}\right)^2 = \left(\frac{P_{R_I}}{R_I}\right)^2 + \left(\frac{P_{R_N}}{R_N}\right)^2 \quad \text{(VI)}$$

The distance, R_N, need be determined but once, by taking the average of a number of comparator readings. The distance, R_I, however, varies with every readjustment of the stereopticon screen and on this account it is probably more convenient to take but a reading or two and allow for a probable error of 0.5 mm. Actual experiment will indicate that this value is about correct.

If D is the total magnification on the stereopticon screen (20,000 to 25,000 diameters for the finest pigments), then,

$$D = D_m \times D_S \quad \text{(VII)}$$

But $D_m = K \times B.L.$

Then the total error in magnification is,

$$\left(\frac{P_D}{D}\right)^2 = \left(\frac{P_K}{K}\right)^2 + \left(\frac{P_{B.L.}}{B.L.}\right)^2 + \left(\frac{P_{D_S}}{DS}\right)^2 \quad \text{(VIII)}$$

The B. L. which enters the third term in equation VIII is usually obtained from but a single measurement and has a probable error of about $\pm$ 1.0 mm. Note that this is not the same measurement of B. L. which enters into the determination of K.

In the results of the work presented in this paper the value of P_D was found to be $\pm$ 0.78 per cent. at 20,000 diameters.

For the calculation of the total error of average particle size, see Section (II), 1.

(I) 5. The direct method of determining magnification described under Section (I), is applicable only when apochromatic lenses are employed.

With a 2 mm. achromatic objective, distortion in the outer zones is so great that an accurate direct determination of magnification becomes impossible. When it is desired to work with such lenses, the following plan must be adopted: Produce a D – B. L. curve, using a low-power objective (16 mm.), together with the ocular that is to be used later on in conjunction with the 2 mm. objective. With this combination of lenses the rulings of the 0.10 mm. division will no longer fall in the outer zones of the field, and will, therefore, be practically free from distortion. Next determine the relative magnifying power of the 2 mm. with that of the 16 mm. objective. This is easily accomplished with a filar micrometer eye-piece, using some suitably mounted object, such as a fragment of a diatom, with sharp edges sufficiently close together.

The relative magnification of the high-power objective, multiplied by the value of K derived for the 16 mm. lens, will give the desired value for K.[9]

(II) 1. It is obvious that the greater the number of measurements from which the average diameter is derived, the nearer will this average be to the true value. As the number of measurements must of necessity be finite, there will always be a probable error due to this fact. This error is calculated from the equation,

$$P_{A_D} = \pm .6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}} \qquad \text{(IX)}$$

where P_{A_D} is the probable error of the average at magnification,

[9] Even in the case of apochromatic objectives where distortion appears to be negligible, it is advisable to employ this method of determining magnification as a check on the direct method.

D; v is the amount the particle differs in diameter from the average, and n is the number of particles measured.

The actual size of the average particle is,

$$A_I = \frac{A_D}{D} \qquad \text{(X)}$$

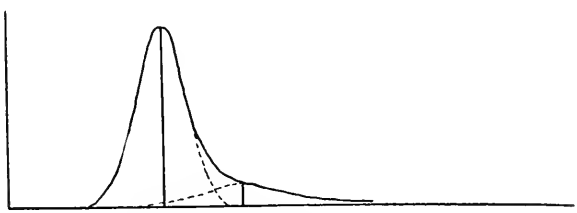
from which the total probable error, derived from the entire process of particle measurement, is obtained, thus:

$$\left(\frac{P_{A_I}}{A_I}\right)^2 = \left(\frac{P_{A_D}}{A_D}\right)^2 + \left(\frac{P_D}{D}\right)^2 \qquad \text{(XI)}$$

The value of P_D is given by equation VIII.

(II) 3. If we have a pigment following a smooth curve law

FIG. 3.



The type of frequency distribution apparently caused by a mixture of two grades of the same pigment.

of distribution, and if it is found that in this material a particle of certain size should occur but once in a thousand times, then it ought not to appear at ali on a negative containing but 200–250 particles. In actual practice such irregularities do happen and affect the average unfavorably. Therefore, in order to secure the most consistent results possible, a criterion of rejection is necessary.

There would be no difficulty in devising a suitable criterion if the curve followed the law of probability to its extremities. Unfortunately it does not always do this, and in such cases is apparently compound and derived from a mixture of different grades of the same pigment. (See Fig. 3.)

The use of any criterion of rejection, based on the mathematics of the probabilty curve, would therefore eliminate *entirely* the lower right-hand branch of such a curve with the result that the average obtained would be far below its most probable value.

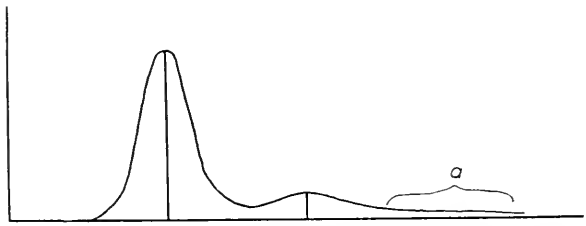
As the equation of a frequency distribution like that shown in Fig. 3 cannot be ascertained, the criterion of rejection, or more

accurately speaking a *method* of rejection, will necessarily be a somewhat arbitrary one.

METHOD OF REJECTION.

The method is to effect the extremity of the curve only. It is applicable when the pigment gives evidence of a smooth, continuous frequency distribution. When it is obvious that the material is composed of two or more grades of the same substance with widely different averages, as shown in Fig. 4, the rejection may

FIG. 4.



A frequency curve showing a mixture of ingredients with widely different average particle size. The method of rejection is applied to the portion of curve marked *a*.

be applied only to the right-hand branch of the curve furtherest from the origin.

Take the following example of the extremity of any suitable curve:

Frequency:	12	10	8	5	2	0	2	0	1	8	1	3
Millimeters:	15	16	17	18	19	20	21	22	23	24	25	26

It will be noted that from mm. 19 to mm. 26 the curve is practically straight and approximately parallel to the millimetre axis. This section may, therefore, be "smoothed" without introducing appreciable error. Bearing in mind that in measuring the images of large particles, such as mm. 21 for instance, there is liable to be an error of $\pm$ 1 mm., then it is reasonable to believe that one of the 21's is perhaps either a 20 or a 22. A 21 should be cancelled and either a 20 or 22 inserted; it does not matter which one is selected.

Upon further examination it appears that there are probably seven 24's too many and two 26's. Eliminating these and rewriting, we have:

Frequency:	12	10	8	5	2	1	1	0	1	1	1	1
Millimeters:	15	16	17	18	19	20	21	22	23	24	25	26

There is still the vacancy at 22 to be accounted for. As 23, 24 and 25 each occur, it is more probable that there should be a 22 rather than a 26. Again rewriting, gives us the final form of the curve:

Frequency:	12	10	8	5	2	1	1	1	1	1	1
Millimeters:	15	16	17	18	19	20	21	22	23	24	25

This distribution is far more rational than the one first given, and is certainly to be preferred. Rejection need not be applied where the method of determining particle size is to be employed only for routine purposes.

(II) 5. With glass lenses and white light, particles as small as 0.30μ will appear *clear,* centred with a black outline or circumference. Those a little less than this in diameter, however, will give for their image a *solid* black dot, resembling on the negative, in appearance and size, the diffraction disks produced by particles very much smaller.

There is consequently a limit, governed by the particle size, below which the method of measurement, described in this paper, is no longer applicable. Recourse must be had then to the use of ultra-violet light and quartz lenses, if we are to measure with reasonable accuracy pigments less than 0.30μ in diameter. Fortunately, for the method, pigments finer than this are exceptionally rare.

(II) 6. F. E. Ross has shown that tanning developers, such as pyro-elon and caustic hydroquinone, cause, upon the drying of the negative, contraction of the image. If it is found necessary to use these developers it is perhaps better to make measurements on the wet negative, care being taken that the heat of the stereopticon does not harm the gelatin emulsion in any way.

WHAT IS MEANT BY "PARTICLE SIZE."

We can speak definitely of the "diameter" of a sphere. If we have, say, a pound of fine spherical shot, each shot equal in regard to volume, then if the diameter of one shot is known it can be stated that the length of this diameter is the "particle size" of the entire one pound of material.

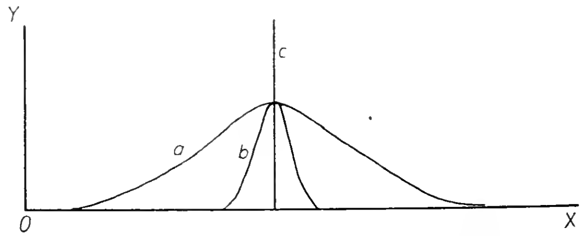
However, in the case of paint and rubber pigments we are dealing neither with spheres nor a perfectly uniform substance, hence the meaning of particle size is less definite here than in the previous illustration.

As pointed out, it is convenient to take as the "diameter"

of a particle that dimension which bears to specific surface the simple relationship shown in equation I. With this much established, let us examine further the significance of the expression "particle size."

If it is stated that the particle size of a sample of zinc oxide is 0.52μ, then it is meant that this is the diameter of the *average* particle. Such a fact may be used to determine specific surface, but aside from this it gives but a poor visualization of the texture of the material, for it neither discloses whether the oxide is composed entirely of particles 0.52μ in diameter nor whether it is a

FIG. 5.



Frequency curves for two pigments of the same average particle size but possessing different uniformities. Under the microscope, pigment *a* will appear to have a greater average diameter than *b*.

mixture ranging from ultramicroscopic particles to grains as coarse as sand and averaging 0.52μ.

This difficulty can be overcome in the following manner: *The Coefficient of Uniformity:* If we have two different pigments giving frequency distribution *a* and *b* (Fig. 5), it would be natural to decide, after a simple comparison under the microscope, that material *a* is the coarser of the two, yet upon actual measurement it will be shown that both pigments have the same average particle size. The reason for this misjudgment is due to the fact that material *a* contains some very large particle which are quite easy to see and consequently attract the eye, while the smaller ones, which it also contains, are difficult to find, and likely to be overlooked.

If this difference between *a* and *b* could be stated mathematically, then such an expression, together with the average diameter, would *completely* express the "particle size" of any given pigment. Fortunately this is quite possible to do, with a fair degree of success.

No doubt the reader has realized that this difference between *a* and *b* is simply one of degree of uniformity and that *b* is the more uniform of the two; and also that the "broader" the curve

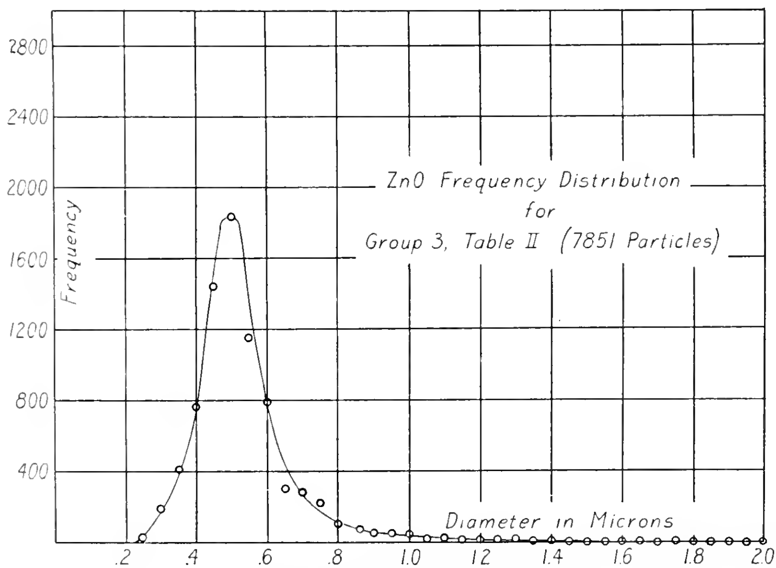
the less uniform the material. This characteristic is governed by the so-called "precision" coefficient, but here it will be referred to as the *uniformity* coefficient and designated by the letter U thus:

$$y = ce^{-U^2(x-a)^2} \qquad \text{(XII)}$$

where c is the maximum value of y and a is the diameter of the average particle.

If all the particles of a pigment were equal in diameter, then

FIG. 6.



Frequency distribution for an average grade of zinc oxide. The measurements were taken from the 30 negatives recorded in Table II.

their frequency curve would be the straight verticle line c (Fig. 5); the uniformity would be perfect and U equal to infinity. Similarly, if no two particles were the same, U would become zero and the curve found to coincide with the x axis.

In practice, U is determined from the following equation:

$$U = \Delta x \sqrt{\frac{n}{2 \Sigma v^2}} \qquad \text{(XIII)}$$

where Δx is the difference between two consecutive values on

the x axis (*i.e.*, the millimetre axis) and should be made equal to unity for convenience: n is the number of particles measured and v the difference (in millimetres) between the particle and its average (at magnification, D, for convenience).

When the curve is symmetrical, U may be used, by substituting its value in equation XII, to find the percentage of any size particle present. This will give us a better idea of the nature of the material than the simple statement of the diameter of the average particle.

As the case sometimes happens, the curve will be asymmetrical, and under such conditions it is no longer permissible to employ U for the purpose just outlined. It should then be called the "Equivalent Uniformity Coefficient" and written U_e. It still remains, however, a constant of the material, and as such is useful for control and identification purposes.

The uniformity of an asymmetrical pigment [10] is equivalent to the uniformity of a symmetrical one having the same values for n and $\sum v^2$ as those possessed by the asymmetrical material.

SOME RESULTS OF MEASUREMENTS.

The author's chief interest has been in the measurement of zinc oxide; hence in deciding upon a material to be used in testing the photomicrographic method of measurement this pigment was selected.

For routine work one negative showing approximately 250 particles [11] will usually give results sufficiently accurate; for a critical test, however, more negatives are required. The measurements presented below are the results of a far more extensive investigation than is ever likely to be found necessary in practice.

Five different bags of the same make of zinc oxide were sampled. Three mounts were made from each sample. Two photomicrographs were taken from each mount, giving a total in all of 30 negatives. The number of particles measured was 7851, and the time of measurement seven hours.

The measurements are given in Table II, in groups of 200-

[10] One giving an asymmetrical frequency curve.

[11] This does not include the marginal particles which are distorted and out of focus.

TABLE II.

Results of Measurements on 30 Negatives in Groups of 200–250, 1200–1500 and 7851 Particles.

	200–250 Particles			1200–1500 Particles.			7851 Particles.		
	Av. Diam.	Prob. Error	Unif. Coef.*	Ave. Diam.	Prob. Error	Unif. Coef.	Ave. Diam.	Prob. Error	Unif. Coef.
	First Negatives.			*1st 5 Negatives Combined in 1 Curve.*					
1A	.595	±.007	.207						
2A	.549	.010	.161						
3A	.522	.007	.219	.543	±.004	.183	.5340	±.0013	.207
4A	.522	.005	.263						
5A	.538	.005	.257						
	Second Negatives.			*2nd 5 Negatives Combined in 1 Curve.*			*30 Negatives Combined in a Single Curve.*		
1A	.548	±.009	.163						
2A	.530	.010	.150						
3A	.562	.007	.226	.547	±.004	.185			
4A	.544	.006	.232						
5A	.538	.007	.216						
	First Negatives.			*1st 5 Negatives Combined in 1 Curve.*					
1B	.518	±.005	.320						
2B	.552	.008	.168						
3B	.522	.005	.309	.539	±.003	.223			
4B	.525	.005	.292						
5B	.560	.007	.238						

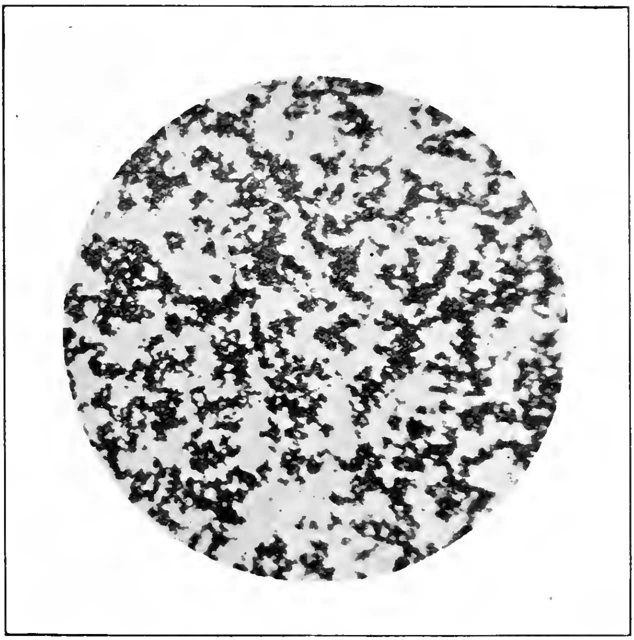
	Second Negatives.			*2nd 5 Negatives Combined in 1 Curve.*		
1B	.527	±.005	.287			
2B	.496	.005	.339			
3B	.522	.005	.296	.515	±.003	.261
4B	.501	.005	.273			
5B	.543	.006	.291			
	First Negatives.			*1st 5 Negatives Combined in 1 Curve.*		
1C	.538	±.007	.203			
2C	.531	.005	.270			
3C	.532	.005	.271	.533	±.003	.223
4C	.556	.008	.186			
5C	.504	.004	.354			
	Second Negatives.			*2nd 5 Negatives Combined in 1 Curve.*		
1C	.520	±.006	.267			
2C	.518	.004	.359			
3C	.524	.007	.201	.520	±.003	.240
4C	.519	.006	.240			
5C	.515	.005	.310			

Av. Probable Error ±1.13%	Av. Probable Error ±.56%	Av. Probable Error ±.24%
Total Error, Including Error in Magnification ±1.37	Total Error, Including Error in Magnification ±.96.	Total Error, Including Error in Magnification ±.82%

* Strictly Speaking, U_e

250, 1200–1500, and 7851 particles. The probable errors shown in the columns are due to the fact that the average diameter is derived from a finite number of particles. These errors are calculated from equation IX. The "total errors," given at the foot of the columns, include the errors in magnification and are derived from equation XI.

FIG. 7.



Timinox, 250 Diameters.

This is the type of pigment photomicrograph commonly found in the literature on paint. It is *not* suitable for particle measurement. The magnification and resolving power, under which the photomicrograph was taken, were both very much too low. It is impossible to detect individual particles. In addition the pigment is not dispersed.

Rejection, discussed under section $(II)_3$, was applied in each individual case. As particles which would be rejected in a small group of 250 would probably be retained in the two larger groups, the values in these latter ones were recalculated each time, that is, the average diameter, $.543\mu$, given in the second group, for instance, is not necessarily the average of the first five diameters, shown in the first group, etc.

The groups are progressive and show the increase in accuracy and reliability with increasing number of measurements.[12]

In Table III are presented the results on the measurements of a variety of the most generally used pigments in the paint and rubber industries. Lamp black and gas black are omitted, however, as it has been impossible to secure negatives of these materials that were sufficiently satisfactory for measurement.[13]

Fig. 7 is the type of photomicrograph which is worthless for particle measurements. The pigments is not only flocculated but no individual particles are shown with certainty and distinctness. The magnification also is much too low. This is the kind of photograph found in technical books on paint.

Fig. 8 shows the type of photograph which must be secured if it is desired to make measurements by the method described in this paper.

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[12] If the uniformity of a material is known, then it is possible to calculate before hand just how many particles it is necessary to measure in order to reduce the probable error to any desired amount. If n is the number of measurements required and P_a the desired probable error, then,

$$n = \left(\frac{.4769\triangle x}{U\ P_A}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(XIV)}$$

If $D = 20{,}000$, then $\Delta x = 1/20{,}000$ mm. As P_A is given in microns, Δx will be $.05\mu$. It must be noted that P_A is not the *total* probable error, *i.e.*, it only includes the error given in section (II) 1. All other errors are independent of n.

[13] It may be stated as a general fact that most technologists who have to deal with fine grained materials have neither the knowledge nor the technique necessary to enable them to make a successful microscopic examination of their products; hence many guesses, far from the truth, have often been given out as to the absolute and relative sizes of pigments. The author has had samples of materials presented to him by technologists who claimed that they were substances too fine to be seen with the microscope, yet in some cases the lowest power objectives were sufficient to resolve them into individual particles. In the case af gas black we are dealing with the finest grained material met with in the paint and rubber industries and, therefore, it is doubtful if there are many technologists capable of handling a pigment of this kind. In all probability the gas black particles are not colloidal, *i.e.*, less than 0.10μ in diameter. They are translucent and are of a brownish gray color. Their size lies most likely between 0.10μ and 0.20μ. This estimate does not take into consideration the very large particles of adamantine which all gas blacks contain.

TABLE III *

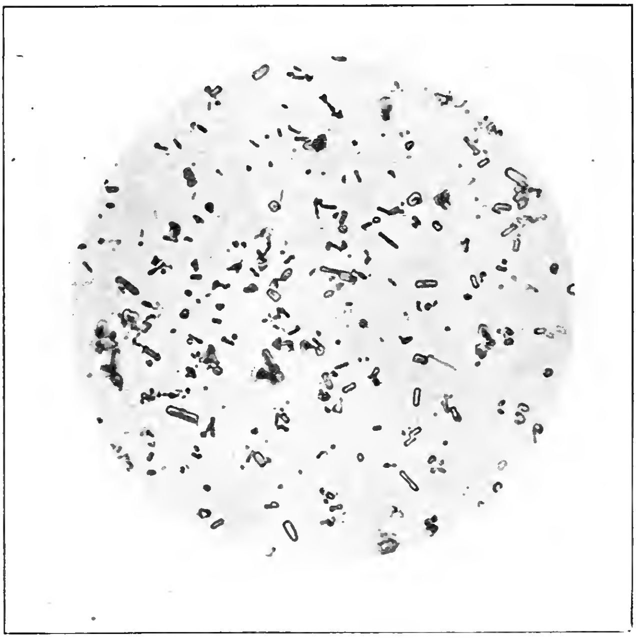
Name	Type	Sample	Negative	Diameter	U
Zinc Oxide	French Process	A		.36	
		B		.39	
		B		.40	
		C		.44	
Zinc Oxide	American Process	A		.46	
		B		.42	
		C		.46	
		D		.42	
		E		.42	
		F		.48	
		G		.46	
		H		.48	
		I	1	.46	
			2	.48	
		J	1	.40	
			2	.38	
Lithopone		A		.33	
		B		.38	
		C		.38	
		D	1	.40	
			2	.37	
			3	.40	
		E	1	.32	
			2	.36	
		F		.50	.210
Iron Oxide	Unadulterated	A		.43	.245
		B		.46	.351
		C		.54	.368
		D		.51	.230
		E		.58	.263
		F		.44	.188
Sublimed White Lead		A		.67	.132
		B		.65	.119
Basic Carbonate of Lead	Carter Process	A		1.03	.067
Basic Carbonate of Lead	Old Dutch Process	A		.75	.086
		B		1.21	
Basic Carbonate of Lead	Mathewson Process	A		1.95	.032
		B		2.39	
Barytes		A		5.33	.045

*The measurements given in this table refer to the average individual particle and do not take into consideration undispersed aggregates.

CONCLUSION.

Those who have devoted much time to the study of particle size will realize that fine-grained materials are of three types, and that each type requires a different method of attack in order to secure particle measurement.

FIG. 8.



Low Leaded Zinc Oxide, 1500 Diameters.

This photomicrograph is well suited for measurement. The crystalline outlines of a number of the particles are clearly shown.

Type A.—Colloidal partcles.

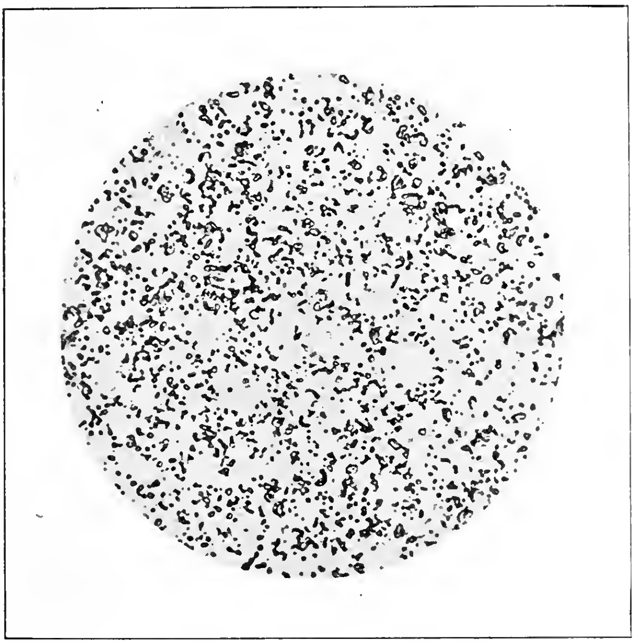
Type B.—Fumed products and fine precipitates such as zinc oxide and lithopone, etc. This type comprises the paint and rubber pigments.

Type C.—Clays and ground materials such as barytes, asbestine, etc. This type includes the so-called "inerts."

A number of methods have been developed for the measurement of colloidal particles. The photomicrographic method is not applicable to this type and therefore it will not be discussed here.

It is hardly necessary to state that the photomicrographic method has been developed expressly for the measurement of particles included under Type B. If applied to any other type it will not be found satisfactory, at least not without special treatment of the sample.

FIG. 9.



French Process Zinc Oxide, 1500 Diameters.

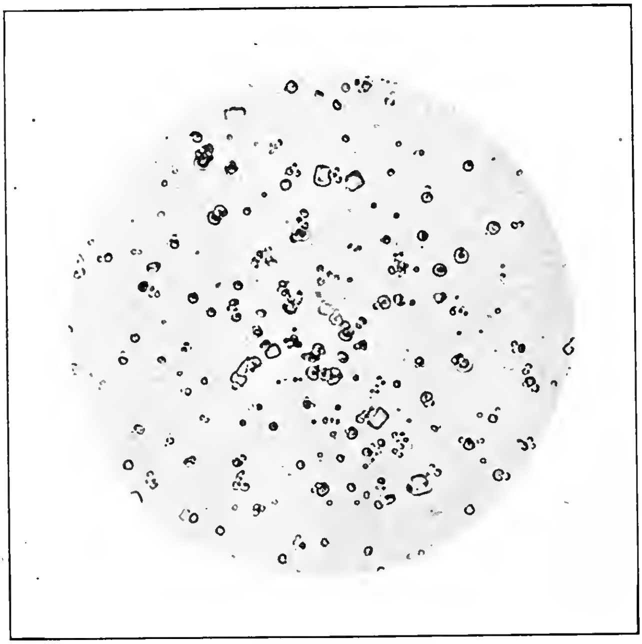
This particular sample of French Process Zinc Oxide approaches the limit of fineness to which the photomicrographic method is applicable. To go below this will require quartz lenses and ultra-violet light.

It seems to the author that the method of grain size determination by the use of a Zeiss-Thoma Counting Chamber employed by Curt Kühn [14] is ideally suitable for Type C, and not for Type B, as Curt Kühn himself uses it. This method necessitates the use of an objective of long working distance giving both low resolving power and magnification. Experience will soon convince one that under such conditions a large percentage of Type B pigment will escape notice altogether and in addition it

[14] *Zeitschrift für Angewandte Chemie*, March 16, 1915.

will not be possible to decide whether flocculates composed of two or three grains are single particles or not. Evidently some such state of affairs did occur for Curt Kühn gives his finest grained lithopone as 372 billion particles[15] per gram, whereas for a lithopone as coarse as 0.40μ and density 4.30, there will be found to be no less than 6850 billion per gram. Similarly for

FIG. 10.



Sublimed White Lead, 1500 Diameters.
A good photomicrograph for measurement.

iron oxide, Curt Kühn gives 308 billion, while this pigment, even when as coarse as 0.50μ and with a density of 5.15, will have 2980 billion per gram. Also with lamp black; here his result is 960 billion as against 19,000 billion, assuming the lamp black particle to be as large as 0.40μ (and it is doubtful if it even attains so large a size). From these facts it does not seem advisable to recommend Curt Kühn's method for Type B pigments.

[15] Particles assumed to be spherical and $U = \infty$.

TABLE IV.*

Showing Relationship of Diameter, Specific Surface, Number of Particles per Gram and Mass of Particle for Zinc Oxide.

Dia. in Microns. μ	Specific Surface in Sq. Meters	Number of Particles per gram, in Trillions	Mass of Particle in Grams
0.70	1.48	.96	1.045×10^{-12}
0.60	1.73	1.54	$.650 \times 10^{-12}$
0.50	2.08	2.64	$.379 \times 10^{-12}$
0.40	2.60	5.17	$.193 \times 10^{-12}$
0.30	3.46	12.24	$.082 \times 10^{-12}$
0.20	5.20	41.40	$.024 \times 10^{-12}$
0.10	10.38	331.20	$.003 \times 10^{-12}$

Specific Surface, surface per gram of material, (S).

Number of particles per gram $= \frac{S}{\pi \mu 2}$ trillion $= n$.

Mass of 1 particle $= \frac{1}{n} \times 10^{-12}$ grams.

* Particles assumed to be spherical and $U = \infty$.

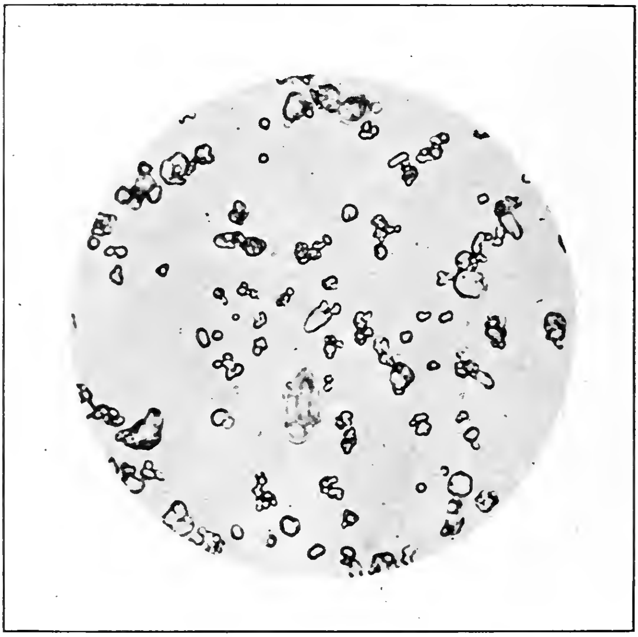
The foregoing paragraphs will probably suggest the question, that if increasing the magnification (550 diameters) employed in the Zeiss-Thoma Chamber method to that used by the photomicrographic method, reveals finer particles and distinguishes between flocculates and individual grains, how do we know that a further increase in microscopic efficiency would not again produce similar results? The answer will depend entirely on the nature of the material examined. For pigments, just on the border line of resolvability, half the particles produce so much defraction that a measurement of their size depends more on an estimate of the intensity of their image than anything else, and hence an increase of resolving becomes a necessity if we desire an accurate measurement of this pigment.

On the other hand, pigments as coarse as .50μ would probably reveal nothing further. This is apparent from the sharp declivity of the left-hand branch of the probability curve. (See Fig. 6.) In this case the number of particles not revealed on the negative is negligible. If this branch of the curve follows the probability law, *then it is always possible to calculate the theoretical number of particles missing,* and so further increase the range over which the photomicrographic method is applicable.

The question has often been asked, how is it possible to know,

upon examining a pigment under the microscope, whether one really sees individual particles or simply aggregates? There are a number of ways of deciding upon this. First, most pigments are crystalline, and if it is possible to see the crystal outlines, even if only a relatively few particles, it is reasonable to believe that the remaining portion of the pigment is of the same order of

FIG 11.



Old Dutch Corroded White Lead, 1500 Diameters.

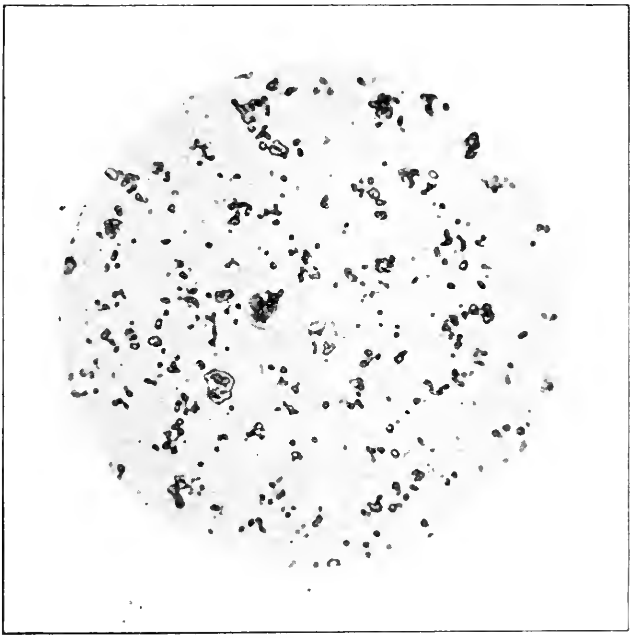
Even though this material is badly flocculated the clear outlines of most of the particles are sufficiently well shown so as to make possible a successful measurement.

magnitude and what we are able to see, therefore, must be, in general, individual particle. Secondly, an individual particle by transmitted light should and does look *clear* and *transparent*, except of course at its boundary, which appears black. Under transmitted light aggregates are always black, regardless of their color. (See Fig. 7.) Thirdly, individual particles in a number of pigments will show a *uniform extinction of their entire face*, when rotated between crossed nicols. Aggregates do not extinguish uniformly on account of the fact that the individ-

ual grains of which they are composed are differently orientated with respect to their optic axis.

In conclusion the author wishes to acknowledge his indebtedness to Mr. Roger Graver for his assistance in producing the many excellent negatives required for this work, and to Mr. Arthur F.

FIG. 12.



Pure Iron Oxide, 1500 Diameters.

As some of the smallest particles shown here are seen to be "clear centered," it is therefore demonstrated that the resolving power and magnification of the microscope are sufficient to show the individual grains of this pigment. On account of this fact the very smallest particles, appearing to be dark centered, are also in all probability individual particles.

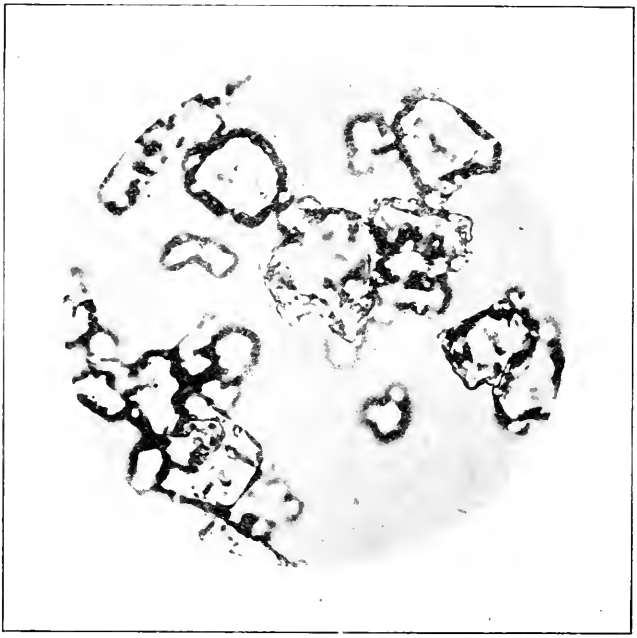
Frantz for his assistance with the innumerable computations that were demanded in the preparation of this paper.

SUMMARY.

1. A method of determining the "diameter" of paint and rubber pigments, by first taking a photomicrograph of the sample, at a carefully ascertained magnification, and secondly again enlarging by means of a stereopticon and then measuring the particles on the projecting screen, is described. It comprises:

(a) The method of dispersing and mounting the pigment so as to make it suitable for photomicroscopy.
(b) The method of determining the magnification of the microscope and stereopticon.
(c) The method of measurement.

FIG. 13.



Barytes, 1500 Diameters.

On account of the low uniformity of barytes it would take about 20 times the number of particles shown here in order to make a successful particle measurement of it.

(d) The calculation of the probable error.
(e) The determination of the uniformity coefficient.

2. The meaning of "particle size" is discussed. That dimension which bears the simplest relationship to specific surface has been selected as the "diameter" of the particle.

3. The results of the measurements of various pigments are given in tables.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE PRODUCTION OF LIQUID AIR ON A LABORATORY SCALE.[1]

[ABSTRACT.]

THE essentials of a plant producing liquid air by the Hampson process are the compressor, purifying train and liquefier. The compressor, usually of four stages, delivers air at room temperature and approximately 3000 pounds per square inch. The compressed air purifying train consists of first, a trap for receiving oil and water, and secondly, suitable containers which are charged with chemical reagents, such as sodium hydroxide, calcium chloride, or lime, for removing carbon dioxide and water vapor. The air thus compressed and purified is delivered to the liquefier, in which, after passing through a coil of copper tubing, the air is allowed to expand freely to approximately atmospheric pressure. Where this drop in pressure takes place there is a corresponding drop in the temperature of the air. The expanded air before leaving the liquefier is caused to circulate around the copper coil which contains the compressed air thus cooling the coil and in turn the compressed air so that on continuous operation a cycle of progressive cooling is maintained until the temperature ultimately reaches the liquefying point. The liquefier is so constructed that the air which is condensed to liquid is delivered into a receiving vessel. The gaseous air exhausted from the liquefier is returned to the intake of the compressor for succeeding cycles because it has been purified and when used repeatedly will be less exhausting on the purifying reagents.

* Communicated by the Director.

[1] Scientific Paper No. 419.

THE CEMENTING QUALITIES OF THE CALCIUM ALUMINATES.[2]

By P. H. Bates.

[abstract.]

The four calcium aluminates, $3CaO.Al_2O_3$, $5CaO.3Al_2O_3$, $CaO.Al_2O_3$, and $3CaO.5Al_2O_3$, which are the only anhydrous compounds of lime and alumina, were prepared in a pure condition by heating together the proper proportion of these compounds. After microscopic examination had shown that homogenous compounds had been formed, the products were finely ground and their cementing qualities when gaged with water were determined.

The two compounds higher in lime reacted very energetically with the evolution of much heat, acquiring practically instantaneous set. The two compounds higher in alumina reacted with water more like Portland cement, but showed higher strength at earlier periods than the latter. It was thought desirable therefore to prepare these in larger quantities and containing such impurities as silica, iron oxide, and magnesia, which would generally be present in lime and alumina of natural origin. The two compounds $CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ were consequently burned in a 2 by 20 foot rotary kiln, varying their composition so that the silica, iron oxide, and magnesia reached limits of 17.38, 3.10, and 3.66 per cent., respectively, as maxima in a series of eight cements. The process of manufacture was entirely similar to that used in the production of Portland cement.

The ground cements were used in making the usual small tension and compressive test pieces and 6 by 12 in. gravel concrete cylinders of 1 : 1.5 : 4.5 and 1 : 3 : 9 proportions. The striking feature of the data obtained from testing these at different periods up to and including three years was the very high 24-hour strength. The rich concretes prepared from four of the cements developed in 24 hours strengths in excess of 2800 pounds per square inch, and the lead concretes from two of the cements gave strengths beyond 1500 lb. at the same period. Consistent gain in strength was obtained up to one year, when one of the cements in the rich concrete gave a strength of 8220 pounds per square inch.

[2] Technologic Paper No. 197.

Test pieces stored in water tended to show retrogression in strength with age. This was also noted with test pieces stored in the damp closet, but to a much less degree. This action may be explained by the fact that the products of the hydration of all the aluminates are a hydrated $3CaO.Al_2O_3$ and hydrated alumina (except in the case of the anhydrous $3CaO.Al_2O_3$, when no hydrated alumina is produced). This latter is the cementing agent in these products, and, being colloidal, it is very susceptible to moisture changes. Large amounts of moisture are taken up in the presence of the latter with consequent swelling of the colloid and reduction in strength.

HOW TO GET BETTER SERVICE WITH LESS NATURAL GAS IN DOMESTIC GAS APPLIANCES.[3]

[ABSTRACT.]

This paper gives the principal conclusions from the laboratory and field investigations of the Bureau on the correct use of natural gas in the home. It is estimated that it would take a million dollars worth of artificial gas each day to replace the waste in natural gas appliances, and it is certain that unless this waste is halted, it will be but a short time when most of the more than two thousand small communities depending on natural gas will have to go back to solid fuel with its many inconveniences, since most of them are not large enough to maintain manufactured plants.

About one-half of the cities in the United States have natural gas, and the consumers number over two and one-half million.

Most of the natural gas stoves have the burners placed two and one-half inches or more below the top of the grid or the solid top which many of them have. This has made it necessary to burn a large volume of gas, supplied with a high pressure and has resulted in a great waste of gas, and very poor service during the winter when the pressure happened to be low.

Tests have shown that by removing the solid top and raising the burners close to the vessel, it is possible to reduce the gas consumption to one-fourth that required with the low set, solid top stoves, and also to improve the service very much.

[3] Circular No. 116.

Other advantages from these changes in the appliances will be the great reduction in the leakage with the reduction in the gas pressure in the distributing systems. Two ounces and even less are sufficient for good service, whereas it has been thought that four ounces were necessary. The loss in leakage at four ounces is approximately forty per cent. greater than it is at two ounces.

The lower the minimum pressure at which the gas companies are allowed to supply the gas to consumers the easier it is for the company to maintain satisfactory pressure conditions. In many cases the line pressure is quite sufficient to give good service, but it is not properly utilized, due to the poor design of the burner and burner orifice, and dirty burners.

THE TESTING OF RUBBER GOODS.[4]

THE purpose of this circular is to describe the methods of physical and chemical testing used at the Bureau of Standards.

An introductory portion gives information about crude rubber and the manufacture of rubber goods. The sources of crude rubber are briefly described, as well as the methods of collection and preparation.

The materials used in the compounding of rubber are classified as follows: Reclaimed rubber, rubber substitutes, vulcanizing and compounding ingredients. The latter are divided into inorganic and organic fillers, inorganic and organic accelerators, and pigments.

The various processes which are common to all branches of the rubber industry are described. These are the washing and drying of the crude rubbers, the compounding or mixing of rubber and ingredients, the calendering and vulcanizing of rubber compounds accompanying the above, illustrations of the experimental equipment used at the Bureau, which represent on a small scale typical rubber machinery.

A brief summary is included of the essential details of the manufacture of pneumatic tires, solid tires, inner tubes, mechanical goods, such as hose, belting, and tubing, and druggists' sundries, such as hot-water bottles and rubber bands.

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[4] Circular No. 38.

The methods of physical testing are described in detail. Complete data are given of the results of the experimental work that has been carried on at the Bureau. These investigations were made to determine the effect on the tensile strength, ultimate elongation, and recovery of a rubber compound by varying the conditions under which the tests are made. Some of these conditions are: The rate at which the specimen is stretched, the temperature, the cross section of the test specimen, the direction in which the test specimen is cut, and the shape of the test specimen.

The comparison of the tensile strength and ultimate elongation of twelve compounds that were aged for varying periods at $158 \pm 2°$ F., in an electric oven, and under ordinary conditions of storage extending over a period of 7 years, are graphically shown.

The methods of chemical analysis are described in detail and include not only the usual methods for the determination of the acetone, chloroform, and alcoholic-soda extracts, free and total sulphur, ash and sulphur in ash, but also those for the determination of barytes, barium carbonate, glue, rubber by combustion of the introsite, total fillers, antimony, cork, leather, wood, and vegetable fibres and cellulose.

The methods adopted by the Joint Rubber Insulation Committee for the analysis of rubber covered wire has been incorporated.

The methods of testing fabrics used in the manufacture of rubber goods are described.

The appendix contains a list of governmental specifications drawn up by the Bureau; a bibliography of the papers published by the Bureau, and of the more important books and periodicals that deal with rubber, and a table of the specific gravities of the most common compounding ingredients used.

PRECISION TEST OF LARGE CAPACITY SCALES.[5]

By C. A. Briggs and E. D. Gordon.

[ABSTRACT.]

THE accuracy that can be obtained from large weighing scales is not generally known among engineers and others concerned in the subject. This paper outlines a scientific and systematic procedure for the accurate test of large capacity compound lever

[5] Technologic Paper No. 199.

scales, by a method which has been developed and used by the Bureau of Standards, largely in connection with its work in testing railroad master track scales, and grain hopper scales; but the plan can be adapted to the test of almost any compound lever scale.

A pointer and graduated scale are arranged for reading the position of the beam; and the errors of the scale are determined from observations made upon the beam while it swings freely. The method of recording data and of determining the results is very similar to that which has been in use in laboratories for precision weighings on fine equal-arm balances. The method of taking and recording the data also tends to eliminate the personal equation, to point out where mistakes are made, when such occur, and give a very complete record of the test which will present very understandable and detailed information to anyone who has occasion to make a critical study of the test.

The method is not suggested for use in the regular routine testing of ordinary compound lever scales, where precision results are not required. The method given here requires the observance of certain details consistent with realizing precision, and requires training and ability to a greater extent in those making the test than is required in the ordinary case.

The procedure of the test is explained with the aid of a record form and computation sheet which was developed in connection with the successful application of the method in the field. In the interest of a uniform and efficient method the scheme outlined is recommended to those who have occasion to carry out tests on large scales where accuracy of a high order is required.

RESULTS OF A SURVEY OF ELEVATOR INTERLOCKS AND AN ANALYSIS OF ELEVATOR ACCIDENT STATISTICS.[6]

By C. E. Oakes and J. A. Dickinson.

[ABSTRACT.]

THIS report gives the results of a field survey of several thousand elevator landings equipped with various types of mechanical and electromechanical interlocks and contact devices. This survey was carried out in connection with the preparation of an Elevator Safety Code, in which work the Bureau engineers have coöperated with the American Society of Mechanical Engineers.

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[6] Technologic Paper No. 202.

The elevators are classified into three groups: Class A, elevators located in buildings in which the service is heavy and where maintenance service is provided; Class B, buildings in which the service is heavy, but where no maintenance service is provided; and Class C, buildings in which the service is light and in which no maintenance service is provided.

The data which were secured in various parts of three states and a number of large cities, are classified under the above grouping, the performance in each group being briefly discussed.

The difference between an electromechanical interlock and a contact device is clearly pointed out and the functions and usual method of operation of each type of device is given.

The comparison of advantages and disadvantages and a comparison of service of each of the three types are given in tabular form. Some suggestions as to possible improvement are added.

Representative statistics of elevator accidents are given: Group I.—Accidents from the entire United States reported by the public press through clipping bureau; Group II.—Industrial elevator accidents reported by various state departments of labor or state industrial boards (these accidents cover employees only); Group III.—Accidents to the public and employees reported by the coroners' offices or elevator inspection departments of large cities.

These statistics have all been reclassified as non-shaft-door and shaft-door accidents, the latter being those that should be eliminated by the use of interlocking devices.

A table of weighted averages of all the statistics is added and shows that 73.8 per cent. of all fatal accidents would probably be eliminated by the use of well-designed interlocks.

The report quotes the A. S. M. E. Elevator Code specifications for interlocks in conclusion.

Electric Furnace Treatment of Nickel-silver.—Among the alloys for which the electric furnace treatment seems best is nickel-silver, as pointed out in a paper by Thompson, presented to the American Electrochemical Society at its last (fortieth) meeting. The specific advantages observed here are: The loss of zinc is less than 1 per cent., the occulsion of gases is minimized, a tougher alloy with less carbonization is obtained. Figures are given showing the avidity with which the alloy will absorb carbon from a graphite crucible as contrasted with one of clay. Thompson also states that in his opinion the electric furnace has

advantages when large quantities of scrap are to be remelted, in minimizing the accumulation of sulphur and carbon, and thus reducing the amount of virgin metal required for the charge.

H. L.

The Age of the Earth.—This question was the subject of a formal discussion at the recent meeting of the British Association for the Advancement of Science. Lord Rayleigh made the opening remarks, reviewing the methods that have been proposed. Lord Kelvin's calculations based on a limit of the sun's heat and the internal heat of the earth have been upset by the discovery of radioactivity. Lord Kelvin gave but a limited duration to the period in which the earth was cool enough to support the life that is now on it, a result which was not acceptable to many geologists and paleontologists, who believed that the evidence of the fossil remains indicated a much longer period. Darwin termed Kelvin's result "an odious spectre."

The changes undergone by uranium have been recently made the basis of calculation, and especially the accumulation of lead in uranium-containing minerals. The upshot of the calculations at hand is a moderate multiple of one billion years as the time during which the earth was suitable for living beings, and data from physics or astronomy afford no definite presumption against this view. Rayleigh waives any discussion of the biologic and geologic data.

J. W. Gregory says that the best-known geologic estimates require to be multiplied ten or twenty-fold in order to agree with the physical estimates. A. S. Eddington suggests that Lord Kelvin's time-scale should be lengthened five-hundred-fold, at least during the stage of evolution. Gregory makes a curious mistake in saying that the claim that geologic time covered only a few score million years was regarded by geologists as of little more use than the " seven days of the Pentateuch." The creation, however, is given in the Pentateuch as having taken only six days.

H. L.

Electrolytic Corrosion of Lead-Thallium Alloys.—Fink and Eldridge in a communication to the recent (fortieth) meeting of the American Electrochemical Society report experiments undertaken with a view to minimize the loss of metal in anodes used in procedures of copper precipitation in Chile. It was found that an alloy of 70 per cent. lead, 20 per cent. tin and 10 per cent. thallium lost only 1.2 pounds per 100 pounds of copper precipitated. It was also found that, in general, alloys with high melting points are more resistant to corrosion. The liquid subjected to electrolysis in the operations studied was a solution of copper sulphate containing nitric and hydrochloric acids. The low corrosion is due to a strongly adherent film formed on the anode.

H. L.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

THE GOLD NUMBER OF COMMERCIAL GELATINES.[1]

By Felix A. Elliott and S. E. Sheppard.

ZSIGMONDY'S method for the preparation of deep red, highly homogeneous, gold hydrosols was modified to the extent that a dilute solution of formaldehyde is added very slowly with thorough stirring until the first color appears. Further amounts were then added by drops until no further change in color took place. The protective action was measured by the amount of gelatine, expressed in milligrams, just necessary to prevent the change in color of 10 cc. of the standard gold solution. Seventeen different gelatines of all grades representing all methods of manufacture were shown to differ but little in their protective action. The classification thus made possible is too rough and, moreover, does not bear any simple relation to those properties of gelatine of chief interest to users of gelatines.

It has been shown that the gold number increases as the concentration decreases, and that it increases the longer the gelatine solution stands or " ages " after it has been made.

The effect of making the gelatines solutions under different conditions was investigated, and it was found that the more dilute the solutions made up the lower the gold number. Subsequent dilution at ordinary temperatures does not change this conclusion.

The state of subdivision of gelatine solutions was very definitely indicated by these gold numbers and confirmed by ultramicroscopic observations. These solutions were shown to contain varying proportions of large and small particles, depending on the temperature at which they were in equilibrium, there being a predominance of large particles at lower temperatures.

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* Communicated by the Director.

[1] Communication No. 118 from the Research Laboratory, Eastman Kodak Company and published in the *Journ. Ind. and Eng. Chem.*, Aug., 1921, p. 699.

THE ABSORPTION OF LIGHT BY TONED AND TINTED MOTION PICTURE FILM.[2]

By L. A. Jones and C. W. Gibbs.

In order to measure precisely the absorption of light by toned and tinted motion picture film, a special instrument was designed and constructed. The optical system of this instrument is so arranged that the transmission value measured is that of the effective transmission of the picture as projected in the standard motion picture machine. Since such a picture is composed of silver deposits which are diffuse in nature, that is, light scattering, they must, in order to obtain the value of effective projection transmission, be illuminated under precisely the same conditions as exist in the projecting machine. Furthermore, since in dealing with toned and tinted film, color differences are involved, it was necessary to use a flicker method for measuring the desired values of transmission. The apparatus constructed for this work is therefore called an "integrating flicker photometer," and measures the mean effective projection transmission of the sample under consideration.

The results obtained in the case of tinted pictures show that the tinting process produces no change in the physical contrast of the picture but merely decreases the transmission. The transmission values for the series of colors examined varied from 26 per cent. in the case of cine violet to 82 per cent. in the case of cine yellow. The results obtained with the dye tone samples show that the decrease in transmission is not directly proportional to the density of the deposit, but that the deposits of higher density are more affected by the treatment than the very low densities. This tends to produce a slight increase in the physical contrast of the picture. The selective action, however, is confined largely to the densities lying on the toe of the curve, which results in a lengthening of the straight line portion of the curve without materially changing the slope of the straight line portion. The transmission values for a series of dye toned samples vary from 43 per cent. for the safranine to 89 per cent. for one of the auramine tones. These values are relative to the transmission of the untoned sample. In the chemical toned samples, the selective intensification is much

[2] Communication No. 122 from the Research Laboratory of the Eastman Kodak Company and published in *Trans. Soc. Mot. Pic. Eng.*, No. 12, p. 85.

more marked, the results being an almost complete straightening out of the unexposed region of the curve. This produces a material increase in the physical contrast and a better tone rendering of the negatives. The values vary from 46 per cent. for the uranium to 69 per cent. for the sulphide tone. On account of its integrating character, the apparatus is adapted to measure the mean transmission of a sample consisting of an uneven distribution of density such as occurs in a cine picture. A large number of pictures representing as nearly as possible the entire range of subjects met with in this work were selected and mean transmission values determined. The results on a group of forty-one samples show an average mean transmission value of 14.59, the mean transmission varying from a minimum of 3.2 per cent. to a maximum of 38.8 per cent.

A New Process for the Recovery of Silver from Fixing Baths. —The silver which is not in the finished picture is almost entirely in the fixing solution. The developer and wash waters contain mere traces, probably mechanically detached from the film. In large scale work the dissolved silver is regularly recovered, and, as the ordinary precipitant for silver, sodium chloride, does not affect the hypo-solution, sodium sulphide is often used, which forms an insoluble sulphide. Recently a German chemist has recommended a compound known commonly as sodium hydrosulphite, which is a powerful reducing agent and throws down metallic silver from the solution in the fixing bath. This compound has industrial application along several lines, considerable amounts being used in reducing indigo in the ordinary methods for dyeing with this color.

An unfortunate confusion in nomenclature of some of these compounds interferes with systematic discussion of their chemistry. The " hypo " of the photographer was at first thought to be the true hyposulphite, but is now known to be a derivative of sulphuric acid, and its correct name according to the modern system is " thiosulphate." The true sodium hyposulphite is Na_2SO_2, while the hypo of the photographer has the formula, $Na_2S_2O_3$. The substance mentioned above as a reducing agent is given the formula, $Na_2S_2O_4$, and receives the name " sodium hydrosulphite." It is not likely that the amateur will care to recover the silver from the fixing bath, but the procedure may be found advantageous for the worker on the large scale. After treatment of a fixing bath with sufficient of the precipitating agent, the bath is revived and may be used again.

H. L.

Problems in Physics. O. W. RICHARDSON. (*Science*, Sept. 30, 1921.)—This address of the distinguished vice-president of Section A of the British Association for the Advancement of Science was delivered at the recent Edinburgh meeting. It is notable not only for its scientific quality but also for its fine literary flavor. Let one instance suffice. "Relativity is the revolutionary movement in physics which has caught the public eye, perhaps because it deals with conceptions in a manner which for the most part is found pleasantly incomprehensible."

On the same subject, dealt with at the very beginning of the address, this is said, "My predecessor in office a year ago reminded you that the theoretical researches of Einstein and Weyl suggest that not merely the material universe but space itself is perhaps finite. As to the probabilities I do not wish to express an opinion; but the statement is significant of the extent of the revolution in the conceptions and fundamental principles of physics now in progress. That space need not be infinite has, I believe, long been recognized by geometricians, and appropriate geometries to meet its limitations have been devised by ingenious mathematicians. I doubt, however, whether these inventive gentlemen ever dreamed that their schemes held any objective validity such as would assist the astronomer and the physicist in understanding and classifying material phenomena. It is not certain that they will; but the possibility is definite. Apart from this, the whole development of relativity is an extraordinary triumph for pure mathematics. Had Einstein not found his entire calculus ready at hand, owing to the purely mathematical work of Christoffel, Riemann and others, it seems certain that the development of generalized relativity would have been much slower. It is a pleasure to be able to acknowledge this indebtedness of physics and astronomy to pure mathematics."

G. F. S.

Dissociations of Sodium and Calcium Cyanamide in Aqueous Solutions.—Naoto Kameyama has made studies on the subject. The growing importance of all nitrogen fixation methods gives to cyanamides practical interest. The communication is part of the results of work at the College of Engineering at Tokyo, and will appear in full in the journal of that institution. The brief account is part of the proceedings of the American Electrochemical Society. Sodium acid cyanamide is hydrolyzed in water-solution to the extent of 4.5 per cent. to 12.9 per cent. in certain dilutions. If the hydrolysis is prevented by an excess of the cyanamide, dissociation occurs to almost the same extent as in the case of sodium formate. Under similar conditions unhydrolyzed calcium acid cyanamide dissociates to the same extent as magnesium formate or calcium nitrate. The conductivity of the cyanamide anion was found to be about that of the formate anion.

H. L.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

BACTERIA IN SUGAR-CANE PRODUCTS.[1]

By Margaret B. Church.

[ABSTRACT.]

CONTAMINATING molds, yeasts, and bacteria gain entrance to sugar-cane products at the sugar house through the air, the mixer, and the spout when massecuite is allowed to accumulate for any length of time. Impure wash water at the centrifugals and open or unclean conveyors are responsible for similar contamination. Molasses was found to contain more microörganisms than wash. The separation of wash from molasses therefore would avail nothing except perhaps to render the molasses a more unfavorable medium for microbial life. The number of organisms in magma increases during storage. The results of an experiment with superheated steam at the centrifugal, parallel to that previously conducted at the Louisiana Experiment Station, indicated that superheated steam is useful in reducing actively growing organisms in sugar and molasses at the centrifugal. Home sugars, however, should be made in a sufficiently clean manner to make the use of superheated steam at the centrifugal unwarranted.

THE DETECTION AND ESTIMATION OF COAL-TAR OILS IN TURPENTINE.[2]

By V. E. Grotlisch and W. C. Smith.

[ABSTRACT.]

THE method outlined includes the following steps: (1) Passing dry hydrogen chloride gas into the liquid, thus converting the pinene into crystalline pinene hydrochloride, also raising the boiling points of the unprecipitated reaction products; (2) distillation of the filtrate under reduced pressure to separate the coal-tar oils

* Communicated by the Acting Chief of the Bureau.

[1] Published in *Sugar*, 23 (1921): 413, 491.

[2] Published in *J. Ind. Eng. Chem.*, 13 (1921): 791.

with a minimum of terpene bodies; (3) sulphonation of the distillate with fuming sulphuric acid, thereby destroying terpenes and converting coal-tar hydrocarbons into sulphonic acids; (4) dilution and steam distillation of the sulphonation mixture to remove undecomposed terpenes or mineral oils; (5) direct distillation of the sulphonation mixture to break up the sulphonic acids, with recovery of the coal-tar hydrocarbons.

After an interim of some years due to the war with Germany the journal *Physikalische Zeitschrift*, is again reaching the library of The Franklin Institute. On the last page of the number for July 15 of this year the reader is surprised to note in capital letters A.E.F. On examination, however, these are found to be the abbreviations not of American Expeditionary Force but of the name of a committee on units and constants. This particular article deals with the method of designating and reading certain vector quantities and Hamilton's operator Nabla.

Under "Personal Notes" one reads of the promotion of a professor of chemistry from the University of Arizona to the corresponding institution in Minnesota, of the appointment of a professor of chemistry to the Artillery College in England, and of another to the University of St. Andrew, Scotland. The death is announced of the former professor of physics at Vienna, Viktor von Lang.

A woman physicist who was graduated with distinction and has been an assistant in an institution of high grade seeks a position in industry—an indication of a tendency much in evidence in the United States in recent years.

S. Hirzel, of Leipzig, advertises a translation of Sir Ernest Rutherford's Bakerian lecture on the structure of the atomic nucleus, explaining that such translations are no longer as formerly a luxury for those who do not read foreign languages with ease but are "unfortunately a necessary Ersatz [Note the famous war-worn word for "substitute"] for foreign publications, often unattainable and generally exorbitant in price." The same firm presents to the public no less than three books dealing with the theory of relativity. Planck's quantum theory and the methods of measuring the enigmatic h form the subject of a fourth book advertised. Between the lines calling attention to Otto Wiener's "Principles of Flight" it is not difficult to read a bit of war history. What but this upheaval would have diverted the interest of the eminent investigator in the field of optics from his chosen pursuits?

G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

ZIRCONIUM.

By J. W. Marden and M. N. Rich.

Zirconium and its alloys or compounds are finding increasing use as an acid resistive metal, for electrodes, for armor and automobile steels, abrasives, pigments, mordants, insulators, fire brick, and other products.

Zircon is a widely distributed mineral, being found in workable quantities in the United States, Canada and Norway. In Brazil large deposits of brazilite are found. The Bureau of Mines has completed an extensive investigation regarding the properties and uses of metallic zirconium and its salts. The results are given in Bulletin 186, "Investigations of Zirconium with Especial Reference to the Metal and Oxide."

DETERMINATION OF OXIDES OF NITROGEN.

By V. C. Allison.

A new method for the determination of oxides of nitrogen has been developed in the Bureau of Mines laboratories, by means of which as low as ten parts of the gas in a million parts of air can be detected. Oxides of nitrogen are intensely poisonous gases, sometimes formed after blasting in mines, and are also developed in certain other industries. The method will be useful in determining ventilation conditions, and hazards from exposure of miners to gases liberated in blasting. The method is described in detail in Technical Paper 249, "The Determination of Oxides of Nitrogen," by V. C. Allison, W. L. Parker, and G. W. Jones.

HOT HIGH-NITROGEN GAS IN A METAL MINE.

By G. E. McElroy.

While investigating the presence of heavy strata gases in certain mines of the East Tintic mining district of Utah, a small, local body of light, very hot gas of high-nitrogen composition was noted in one of the mines. Observations and analyses indicate that this light gas was resulting from very rapid oxidation of

* Communicated by the Director.

finely disseminated pyrite, in lead-silver sulphide ore. The gas was actually mine air which had lost a large proportion of its oxygen content by reaction with the pyrite. This body of gas was hanging in a local high spot caused by caving, in the end of a 5 by 7 foot cross-cut. Fifty feet distant an air current was entering from a raise from below.

Results of analyses for samples taken show that the gas is black damp composed almost wholly of nitrogen. One sample taken four feet above the vapor level and one foot below the roof had a temperature of 175.5° F., humidity 100 per cent., CO_2 .38, O_2 2.49, N_2 97.13 per cent., as reported. The calculated air-free black damp content was 88.10 per cent., composed of 0.42 per cent. CO_2 and 99.58 per cent. N_2.

That the process of oxidation was still in rapid progress was evidenced by the fact that, although the volume of the body of gas was practically constant, a thin stream of hot gas was flowing along the roof to the air current fifty feet away.

The gas had a strong, musty, sulphur odor and had a suffocating effect when breathed. Attempts to prove the presence of sulphuric acid vapor in the body of gas were not determinate, although a very slight amount was undoubtedly present. The presence of this body of gas in this particular mine probably represents the first step in the production of certain heavy strata gases high in carbon dioxide content that affect mines in this district, that is, the production of residual atmospheres by oxidation of sulphides, accompanied by the production of heat, sulphur dioxide and sulphuric acid, the succeeding step being the production of carbon dioxide by reaction of the acid with carbonates. Further details are given in a recent report issued by the Bureau of Mines in mimeograph form.

Chinese Leather.—According to LLOYD BALDERSTON (*Jour. Am. Leather Chem. Asso.*, 1921, xvi, 367–374), the Chinese obtain red leather by the use of mangrove bark as a tanning material. They manufacture white leather by tanning with alum, Glauber salt, (sodium sulphate), or smoke. In Manchuria, leather is tanned by the use of yogurt or fermented milk. In a few Chinese tanneries, leather is manufactured according to Western methods. In addition to the oaks, several species of native Japanese trees may serve as a source of tannin for the leather industry. Thus the bark of coniferous trees is a waste product of the paper pulp industry; yet the amount of this bark wasted yearly in Japan contains tannins worth approximately $100,000.

J. S. H.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, October 19, 1921.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, October 19, 1921.

VICE-PRESIDENT MR. COLEMAN SELLERS, JR., *in the Chair.*

Additions to membership, since last report, 14.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The Chairman then announced that the next business of the meeting would be the presentation of medals and certificates to gentlemen whose inventions had been examined by the Committee on Science and the Arts and found worthy of recognition by the Institute. He then recognized Dr. Harry F. Keller who introduced Dr. Byron E. Eldred, of New York City, recently awarded the Elliott Cresson Medal for his invention of "Low Expansion Leading-in Wire for Incandescent Electric Lamps." In accepting the Medal and Certificate from the Chairman, Doctor Eldred expressed his appreciation of this recognition of the Institute and said that in his opinion such awards would greatly stimulate the efforts of recipients in the field of physical research.

Dr. H. J. M. Creighton was then recognized and gave an account of the process of water-proofing fabrics, invented by Mr. Alfred O. Tate, of Cranston, Rhode Island, who had been awarded the Howard N. Potts Medal for his process. He then introduced Mr. Tate to the Chairman who presented him with the Medal and Certificate. Mr. Tate thanked the Institute for the high honor conferred upon him and expressed his great appreciation of it.

The paper of the evening on "The Delaware River Bridge between Philadelphia and Camden" was presented by Dr. Ralph Modjeski, Chief Engineer of the Delaware River Bridge Joint Commission. The speaker gave an account of the comparative study and considerations which lead to the adoption of the suspension type of bridge and described the salient features and characteristics of the design. The subject was illustrated by lantern slides from the engineers' drawings and views of the bridge as it will appear when completed.

A unanimous vote of thanks was extended to Dr. Modjeski and the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 5, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, October 5, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following reports were presented for final action:

No. 2759: Screw Thread Comparator. The Edward Longstreth Medal to Governor James Hartness, of Springfield, Vermont.

No. 2768: "Once-Over" Tiller. The Edward Longstreth Medal to Mr. Thomas Willing Hicks, of Minneapolis, Minnesota.

No. 2773: Photo-Elastic Method of Determining Stress. The Howard N. Potts Medal to Dr. E. G. Coker, of the University of London, England.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, October 11, 1921.)

RESIDENT.

MR. W. L. DEMPSEY, 618 Perry Building, 1530 Chestnut Street, Philadelphia, Pennsylvania.

MR. LEON W. NICHOLS, 5840 Warrington Avenue, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

DR. RAYMOND F. BACON, Chemists Building, 50 East 41st Street, New York City, New York.

MR. A. W. K. BILLINGS, Canadian Engineering Agency, 115 Broadway, New York City, New York.

MR. CLARENCE R. CLAGHORN, 715 Continental Building, Baltimore, Maryland.

MR. GEORGE E. CABOT, East Valley Road, Montecito, Santa Barbara, California.

MR. JAMES M. CAIRD, Proctor's Building, 92 Fourth Street, Troy, New York.

MR. H. V. COES, 5901 Wayne Avenue, Germantown, Philadelphia, Pennsylvania.

MR. F. J. COLE, 640 South Hill Avenue, P.O. Box 459, Pasadena, California.

MR. PATRICK B. DELANY, South Orange, New Jersey.

MR. R. E. GILLMOR, Van Rensselaer Avenue, Stamford, Connecticut.

MR. BAYARD GUTHRIE, R.F.D. No. 2, Ocean Springs, Mississippi.

MR. RICHARD HOWSON, 36 Mansion Avenue, Haddonfield, New Jersey.

DR. JOHN PRICE JACKSON, 129 Coulter Street, Ardmore, Pennsylvania.

MR. I. N. KNAPP, 6813 Fifth Street, N. W., Takoma Park, District of Columbia.

MR. CONRAD LAUER, 233 Hortter Street, Germantown, Philadelphia, Pennsylvania.

MR. WILLIAM MAUL MEASEY, Box 208, Haverford, Pennsylvania.

MR. CHARLES W. SOULAS, 1108 Sansom Street, Philadelphia, Pennsylvania.

MR. CHARLES A. STONE, Stone & Webster, 120 Broadway, New York City, New York.

MR. S. WEINBERG, Brown Palace Hotel, Denver, Colorado.

MAJOR R. A. WIDDICOMBE, 4639 Beacon Street, Chicago, Illinois.

NECROLOGY.

Mr. Lewis Audenried, Eddystone, Pennsylvania.

Mr. Alfred E. Burk, 925 N. Third Street, Philadelphia, Pennsylvania.

Mr. George R. Henderson, The Aldine Hotel, Philadelphia, Pennsylvania.

Captain A. F. Lucas, 2300 Wyoming Avenue, Washington, District of Columbia.

Prof. J. W. Richards, Lehigh University, Bethlehem, Pennsylvania.

Mr. Paul L. Wolfel, Oliver Building, Pittsburgh, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

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Northampton Polytechnic Institute, Catalogue for 1921–1922. London, England, 1921. (From the Institute.)

Northern Engineering Works, Bulletin No. 520-B, Electric Traveling Grab-Bucket Cranes; Bulletin No. 543, Northern Electric Hoists. Detroit, Michigan, no date. (From the Works.)

Oilgear Company, Bulletin No. 2, Variable Speed Hydraulic Power Transmissions. Milwaukee, Wisconsin, no date. (From the Company.)

Pacific Tank and Pipe Company, Catalogue No. 12, Mining Tanks. San Francisco, California, 1921. (From the Company.)

Pawling and Harnischfeger Company, Circulars, The New Shovel Attachment and The New Skimmer Scoop Attachment. Milwaukee, Wisconsin, no date. (From the Company.)

Pearson-Scott Company, Booklet, The Iron Man. Indianapolis, Indiana, no date. (From the Company.)

Pennsylvania Railroad Company, Seventy-fourth Annual Report for 1920. Philadelphia, Pennsylvania, 1921. (From the Company.)

Plymouth Cordage Company, Booklet, Plymouth Rope and the Merchant Marine. North Plymouth, Massachusetts, 1918. (From the Company.)

Protected Seat Valve Company, Catalogue No. 1, B. & O. Protected Seat Valves. Pittsburgh, Pennsylvania, no date. (From the Company.)

Purit Specialties, Ltd., Booklet No. 4, describing Electrical Appliances. Birmingham, England, 1921. (From the Company.)

Rail Welding and Bonding Company, Instruction Manual. Cleveland, Ohio, no date. (From the Company.)

Ransome, A., and Company, Ltd., Illustrated Catalogue of Patented and Improved Cask-Making Machinery. Newark-on-Trent, England, 1921. (From the Company.)

Rockwell, W. S., Company, Bulletin No. 223, Oil and Gas Burners. New York City, New York, no date. (From the Company.)

Reading Brass Works, Inc., Catalogue No. 1, Illustrating Standard Chandlelier Brass Castings and Fittings. Reading, Pennsylvania, no date. (From the Works.)

Sankey, Joseph, and Sons, Ltd., Pamphlet, Sankey Steel Storage Bins. Wellington, England, 1920. (From Messrs. Sankey and Sons.)

Schramm, Chris D., and Son, Inc., Catalogue No. 11-C, Air Compressors, Portable and Stationary. West Chester, Pennsylvania, no date. (From the Manufacturers.)

Schutte and Koerting Company, Booklet, Industrial and Power Plant Appliances, Catalogue C, Section 1, Adhesion Oil Separator; Section 2, Dry Air Filter. Philadelphia, Pennsylvania, no date. (From the Company.)

Steward Davit and Equipment Corporation, Circulars describing Life Boats and Davits. New York City, New York, no date. (From the Corporation.)

St. Joseph's College, Catalogue, 1920-1921, and The High School Department, Annual Catalogue, 1920-1921. Philadelphia, Pennsylvania, 1921. (From the College.)

Sullivan Machinery Company, Bulletin No. 78-A, Sullivan Dry Vacuum Pumps. Chicago, Illinois, 1921. (From the Company.)

Tasmania Department of Mines, Underground Water Supply Paper No. 1. Launceston, Tasmania, 1921. (From the Department.)

Tracy Engineering Company, Bulletin No. 1, Quality of Steam by the Throttling Calorimeter. San Francisco, California, 1921. (From the Company.)

Union Electric Manufacturing Company, Catalogue No. 1380, Electrical Controlling Devices. Milwaukee, Wisconsin, 1921. (From the Company.)

United States Department of Commerce, Fourteenth Census of the United States taken in the Year 1920, vol. 1. Washington, District of Columbia, 1921. (From the Department.)

United States Department of Commerce, Foreign Commerce and Navigation of the United States for 1920. Washington, District of Columbia, 1921. (From the Department.)

University of Montana, Bulletin, Geology and Oil and Gas Prospects of Central and Eastern Montana. Butte, Montana, 1921. (From the University.)

University of Princeton, University Register for 1921-1922. Princeton, New Jersey, 1921. (From the University.)

Utility Safety Appliance Corporation, Pamphlet, Safeguarding Vertical Transportation. New York City, New York, no date. (From the Corporation.)

Virginia Geological Survey, Bulletin No. 2, The Geology and Coal Resources of Dickenson County, Virginia. Charlottesville, Virginia, 1921. (From the Survey.)

Waltham Department of Public Works, Annual Report for 1920. Waltham, Massachusetts, 1921. (From the Department.)

Ward-Leonard Electric Company, Bulletin No. 54, Vitrohm Resistance Boxes. Mount Vernon, New York, 1921. (From the Company.)

Warren Steam Pump Company, Bulletins No. 101, Steam Heat Vacuum Pumps; No. 102, Horizontal Duplex Piston Pumps; No. 103, Vertical Single Piston Pumps; No. 104, Horizontal Piston Pumps; No. 106, "Eclipse" Valve Gear for Single Pumps; No. 107, Duplex Outside Packed Plunger Pumps; No. 108, Duplex Automatic Pumps and Receivers; No. 109, Vertical Duplex Piston Pumps; No. 110, Single Outside Packed Plunger Pumps; No. 105, Useful Information for Designing and Operating Engineers. Warren, Massachusetts, no date. (From the Company.)

Watson and Sons, Bulletin No. 32-S, Duplitized X-ray Films and Accessory Apparatus. London, England, no date. (From Messrs. Watson and Sons.)

Wayne Tool Manufacturing Company, Catalogue No. 5, Reamers. Waynesboro, Pennsylvania, no date. (From the Company.)

Weller Manufacturing Company, Catalogue No. 35-D, Spiral Conveyors. Chicago, Illinois, no date. (From the Company.)

Wirt Company, Dim-A-Lite Catalogue. Philadelphia, Pennsylvania, 1921. (From the Company.)

Wittenmeier Machinery Company, Catalogue of Refrigerating Apparatus. Chicago, Illinois, no date. (From the Company.)

BOOK NOTICES.

National Advisory Committee for Aeronautics.

Report No. 117, The Drag of Zeppelin Airships, by Max M. Munk. 11 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

This is a discussion of the results of tests with Zeppelin airships, in which the propellers were stopped as quickly as possible while the airship was in full flight. In this paper the author refers to the theory involved in these tests and to one scientifically interesting fact which can be derived from them and which has not yet been noted.

The chief general question concerning these tests is, of course: Does the negative acceleration of an airship with stopped propellers supply proper data for determining the drag of the airship when in uniform flight? This can not absolutely be answered in the affirmative, the two phenomena not being identical in principle. It is believed, however, that in this particular case the agreement is sufficient and that the data obtained from the test are the true or, at least, the approximate quantities wanted.

Report No. 121, The Minimum Induced Drag of Aerofoils, by Max M. Munk. 18 pages, quarto. Washington, Government Printing Office, 1921.

The paper contains some theorems concerning the arrangement of airplane wings which are of considerable practical interest. In particular, it shows the theoretical reasons for the decrease of drag which accompanies all increases in the aspect ratio or lateral extension of a wing. The efficiency of a given arrangement of wings may be calculated from the formulæ derived in this paper.

The Production of Eastern Kentucky Crude Oils. By Willard Rouse Jillson. Pamphlet, 8vo., 99 pages. Winchester, Kentucky, The Cumberland Pipeline Company, 1921. Private edition.

This is principally devoted to statistics of the production of wells in the eastern third of Kentucky, with comments, especially a discussion of the question of depletion. Several pages of prefatory matter give details of the oil-producing sands. The locations of the pools are indicated by a map. Oil supply is now such an important question that all exact information is welcome.

Henry Leffmann.

A Text-book of Pharmacognosy. By Heber W. Youngken, Ph.M., Ph.D., Professor of Botany and Pharmacognosy and Director of the Botanical Garden of the Philadelphia College of Pharmacy and Science. 8vo., 509 pages, contents, index and 350 illustrations. Philadelphia, P. Blakiston's Son and Company. Price $6.00 net.

In this well-written and well-printed volume, Dr. Youngken has included a vast amount of information upon one of the most important topics of applied microscopy. The great mass of crude drugs is drawn from the vegetable world, but the animal division yields a few. This material is subject to much adulteration, and also to many changes from conditions that are what may be called natural. Processes of decomposition of the type commonly called "spontaneous" go on frequently, and the attacks of insects are also productive of great injury. In the naming and describing of the drugs the author follows, of course, the United States Pharmacopœia and the National Formulary. An interesting summary is given of the history of pharmacognosy. The term was introduced by Seydler, in 1815, meaning simply the "knowledge of drugs," but, as noted, the fact that plants were in remote times collected for use as medicines shows that the earliest "herb doctors" had some system of recognition. The first written enumeration of such materials is that of Dioscorides, compiled about three quarters of a century before the present era. Centuries elapsed before further systematic work was published, it being stated that this was by an Arabian physician in the thirteenth century.

Turning to the matter of the book, after about 30 pages of preliminary information, the individual drugs are taken up and the characteristics of genuine samples are given. The adulterations are then detailed. The extensive use of excellent drawings and photographs adds much to the usefulness of the book. Most of these are presumably the work of the author, with some assistance of others and are very clear and distinct. In a few cases of sections of stems, the details are not minutely sharp, but always clear enough for recognition. In making photomicrographs of vegetable preparations, the use of a red screen will often be found advantageous. This lengthens the exposure considerably, but seems to give greater sharpness with ordinary light. It seems to the reviewer that the approximate degree of magnification should be entered with each figure.

Every page of the book gives evidence of thorough familiarity with the field, painstaking and persistent study of details, careful selection of data and vivid presentation of all the facts. The book will be of great service not only to the pharmacologist, but to the chemist engaged in analytical work in connection with supervision of food and drugs. It is one more gratifying evidence that American work is acquiring a dominance in scientific fields. A comprehensive table of contents and an excellent index are commendable features. The mechanical execution is of very high type. The text is clear and correct. The book is highly creditable to both author and publisher and will find a wide field of usefulness.

HENRY LEFFMANN.

WITHIN THE ATOM. A Popular View of Electrons and Quanta. By John Mills, Fellow, American Physical Society. 12mo, 215 pages, 36 illustrations in the text and 4 plates. No index. New York, D. Van Nostrand Company. Price, $2.00 net.

The theories that matter is discrete and that the ultimate particles are extremely minute, indivisible and indestructible date, in outline, from about five hundred years before the beginning of the present era. Unfortunately,

only scanty fragments of the writings of the early Greek philosophers have come down to us, and some of this material is known through quotations by writers who were not wholly in sympathy with those they quoted. From the limited information we have of scientific thought in this early age, it seems that a materialistic and agnostic spirit was quite marked, and Cumont has shown in his essay on "Astrology and Religion" that the earliest Greek philosophers opposed the view that the stars had any influence on human beings, declaring that all the stars were merely balls of fire. Lucretius, in the first century of the common era, gives a very elaborate discussion of the nature of matter, and compares the elements and compounds, respectively, to the letters and words of a language. All this early philosophy must have been reached deductively, as we have no reason to believe that experimental science had any noticeable development.

The book before us is offered, we are told in the preface, for readers who have no previous knowledge of electricity, mechanics or chemistry. There is no question of the author's familiarity with the modern views, and of the earnest effort he has made to present the complicated phases of these views in an attractive form, understandable by the ordinary reader. How far he has succeeded in this effort is a serious question. It would appear from the fact that on the title page he lays no claim to a college degree or a teaching experience, that he has had but little association with the student body, and, therefore, probably still less with the "man in the street," to whom the book is specially intended to appeal. Far be it from our intention to claim that a college degree is necessary to constitute a successful author of a text-book, but abundant experience demonstrates that capacity for giving instruction is rarely inborn, and even when the person has naturally such talent, much experience is needed to develop its full efficiency. Even the greatest geniuses are better for some training.

The literary style is in many places brilliant, but again often turgid and too highly latinized for easy comprehension by the general reader. The essay begins by representing the atom as composed of two classes of particles, "electrons" and "protons." The latter word seems to be coined, although it is introduced somewhat vaguely. It is presumably the positive nucleus of other writers. Reference is made to the mutually repellent powers of electrons and protons, respectively, and to their mutually attractive powers for each other. The analogy of sex attraction, which though very often used in this department of science, is wholly irrelative, is suggested, but is rejected because it will involve "connotations of animistic bias." This sentence will remind one of the conversation concerning Buck Fanshaw's funeral. Later, however, we are told that the picture that we form is like a state of society in which "promiscuity prevails." So the "triangle" is now in chemistry!

The reviewer is compelled to express the view that the literary form in which the matter of this book is cast has seriously injured it. New terms are unnecessarily introduced. The terminology of science grows fast enough without forcing. Whoever introduces a new term without good reason, let him be anathema. The words "pellate" and "tractate" are used as substitutes for "repel" and "attract" to avoid the "animistic bias." They are

apparently not the author's coinage, but their use seems unnecessary. The absence of an index is to be condemned.

The mechanical execution of the book is good; numerous clear illustrations and several fine plates will aid materially in understanding the several chapters.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Die Technik der Elektrischen Messgeräte, von Dr. Ing. George Keinath. 448 pages, illustrations, 8vo. Munich and Berlin, R. Oldenbourg, 1921. Price, in paper, 112 marks.

Imperial Institute: Monographs on Mineral Resources with Special Reference to the British Empire; Silver Ores, by H. B. Cronshaw, B.A., Ph.D., A.R.S.M. 152 pages, illustrations, 8vo. London, John Murray, 1921. Price, in paper, 6 shillings, net.

The Transit: Published annually by the College of Applied Science, University of Iowa. Vol. 21, 70 pages, illustrations, 8vo. Iowa University, Iowa City, 1921.

The Photo Miniature, No. 183, Color Photography, an authoritative summary of the progress made toward the final solution of the problem, with a clear explanation of the principle underlying the methods of to-day and to-morrow. 144 pages, illustrations, 12mo. New York, Tennant and Ward, 1921. Price forty cents. (Contains a very well written and plain statement, by Dr. C. E. K. Mees, of the principles and present practice in color photography, giving several of the most recent suggestions for color cinamatography.)

U. S. Bureau of Mines: Bulletin 186, Investigations of Zirconium, with especial reference to the metal and oxide. Historical Review and Bibliography, by J. W. Marden and M. N. Rich. 152 pages, illustrations, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, June, 1921, by W. W. Adams. 22 pages, 8vo. Technical Paper 261. Oil-camp Sanitation, by C. P. Bowie. 32 pages, illustrations, 8vo. Washington, Government Printing Office, 1921.

Technical Books of 1920. A selection. 28 pages, 16mo. Brooklyn, New York, Pratt Institute Free Library, 1921.

National Advisory Committee for Aeronautics: Sixth Annual Report, 1920, including Technical Reports Nos. 83 to 110. 717 pages, illustrations, plates, diagrams, quarto. Technical Notes, No. 31. Crippling Strength of Axially Loaded Rods, by Fr. Natalis. 34 pages, plates, quarto. Technical Notes, No. 61, Performance of a Vane Driven-gear Pump, by R. H. Heald. 10 pages, diagrams, quarto. Technical Notes, No. 64, N. A. C. A. Recording Air-speed Meter, by F. H. Norton. 5 pages, plates and diagrams, quarto. Technical Notes, No. 70, The Effect of Staggering a Biplane, by F. H. Norton. 3 pages, diagrams, quarto. Washington, Committee, 1921.

CURRENT TOPICS.

The Swiss Commission on Atomic Weights.—*Helvetica Chimica Acta* (1921, iv, 449) gives the report of a commission appointed by the Swiss Chemical Society concerning the international revision of atomic weights. The commission consists of Bernoulli, Dutoit, Guye and Treadwell. The report, after the usual formal preamble, takes up the history of the work. It was in 1903 that the four leading chemical societies, those of America, Great Britain, France and Germany, agreed upon a joint action for annual revision of the table of atomic weights. During the early years of the world war, the reports appeared with the signatures of all four members, but the report for 1917 was signed only by the American, British and French members—Clarke, Thorpe and Urbain, respectively—and appeared only in the journals of those respective societies. In 1918 and 1919 the *Bulletin* of the French society did not publish the table. Since 1917, a table has appeared in the *Berichte* signed only by Ostwald, being merely a reprint of that of 1916.

It seems that this unrevised table has been maintained as official in Germany so that at the latest publication the following are among differences observed:

	International	German		International	German
Ar	39.9	39.88	N	14.008	14.1
B	10.9	11.00	Th	232.15	232.4

It is admitted on all sides that such a condition should not be continued. Confusion arises from the fact that German publications may use either the international or the German figures, generally the latter, the French chemists will, of course, be likely to use the former, and the Swiss chemists will hesitate between the two sets. Some complaints have arisen that the committee changes the weights too frequently and rather hastily. The effects of the war are seen in the recent publications, for determinations have been accepted which rest upon isolated work, not yet subject to control. The criticism is made that the international committee seems to be dominated by a tendency to adopt the newer figures without the necessary control.

The Swiss commission recommends that all the atomic weights not subject to revision since 1916 and found in both tables may be used, except that a reservation is made in the atomic weights of sulphur and carbon, too hastily changed in 1915–16, it being advised to adopt the values respectively of 12.00 and 32.07. As regards the other figures, the following rules are offered:

If the newest values differ from older by from 1/1000 to 1/10,000 they are to be admitted if confirmed by at least two independent methods.

If the differences are from 1/1000 to 1/100 admit them only if derived from at least three independent methods.

Applying these rules, the Swiss table will have but two modications, to wit: N = 14.008 and B = 10.90. It is preferred to mark F as 19.00 rather than 19.0. For atomic weights referred to oxygen, decimals suggesting an accuracy higher than 1/10,000 may be suppressed.

Referring to the atomic weights of radium and niton, it seems desirable to mark these so that the difference is exactly 4, hence niton may be assigned 222, radium being 226. For the ordinary work of the laboratory, especially in organic analysis, it is thought that no important error will occur if the round numbers for certain elements are used as heretofore—C 12, Cl 35.5, H 1 or 1.01, N 14, S 32. It is understood that unless the contrary is stated, analyses published in the Swiss journal will be based on these numbers.

It is further recommended that the revision be made standard for each decade, the various researches being accumulated during such a period being utilized in the revision. In the interval new figures to be introduced only if they are obtained by several different methods with concordant results.

The article is supplemented by a complete table for use of Swiss chemists, giving the names of the elements in three languages, the alphabetical arrangement being based on the French names.

H. L.

An Extension of the Range of the McLeod Gauge. A. H. PFUND. (*Phys. Rev.*, July, 1921.)—In the usual form of this gauge the pressure of a rarefied gas is derived thus. A known volume of the gas is driven by a rising column of mercury into a capillary tube where its volume can be measured and its pressure read from the difference of level of the mercury inside and outside the tube. If the original volume be 1000 times as great as the volume after compression, for example, then the original pressure in accordance with Boyle's Law was one-thousandth of the pressure after compression. "The sensibility limit has been reached when the length of the trapped air column and the difference in level of the two mercury columns are of the order of magnitude of 1 mm." The smaller the pressure of the trapped air that can be accurately measured the smaller the pressure of the uncompressed gas that can be measured in the gauge. Professor Pfund discards the measurement of pressure by the difference of level of mercury columns and replaces it by the more sensitive hot-wire gauge. A filament of fine tungsten wire was sealed

into the upper end of the capillary tube into which the air is compressed. It forms one of the four arms of a Wheatstone Bridge. If the bridge be balanced so that the accompanying galvanometer shows no deflection, and if the pressure of the gas surrounding the wire be changed, then the temperature assumed by the wire changes and its electrical resistance also changes. This is followed by a deflection of the galvanometer, the amount of which depends on the change of pressure of the gas. Hence from this deflection the amount of the change of pressure can be inferred from a calibration curve. The addition of the hot-wire gauge makes it possible to measure pressures one three-hundreth as small as can be measured without its assistance. The range of the improved gauge is from .275 mm. to 1.7×10^{-7} mm. of mercury.

G. F. S.

Thermal Expansion of Aluminum-Zinc Alloys.—A. SCHULZE. (*Physik. Zeit.*, July 15, 1921.).—For all the alloys examined in which the percentage of zinc ranged from 12.5 to 87.5 it was found that there was a temperature interval through which the length of the specimen determined for rising temperature was less at the same temperature than that obtained as it was cooling down. When temperatures are plotted as abscissas and lengths as ordinates, all the curves are nearly straight lines except at the interval mentioned above, where they resemble hysteresis curves in form. The largest area of such a quasi-hysteresis loop was got with an alloy, 25 per cent. aluminium and 75 per cent. zinc. For a piece of this composition one meter long at 20° the length at 270° with rising temperature was 107.65 mm., while at the same temperature but with falling temperature it was 109.62 mm. It had previously been known that such alloys having been heated sufficiently high and then allowed to cool undergo a change in crystallization at 256°. In this probably lies the explanation of the phenomenon.

G. F. S.

Improved Test for Cottonseed Oil.—In Halphen's test for the detection of the presence of cottonseed oil in olive oil, the reagent is a 1 per cent. solution of sulphur in a mixture of equal volumes of carbon disulphide and amyl alcohol. Equal volumes of the reagent and the oil are mixed, and heated for 15 minutes in a boiling aqueous solution of sodium chloride. A reddish color develops if cottonseed oil be present. R. A. KUEVER, of the University of Iowa (*Jour. Am. Pharm. Asso.*, 1921, x, 594–595), has improved both the reagent and the technic in this test. For the reagent, he uses a 1 per cent. solution of sulphur in a mixture of equal volumes of carbon disulphide and pyridine; the sulphur is dissolved in the mixed solvents by heating gently beneath a

reflex condenser. A sample of the oil to be tested is mixed with its own volume of the reagent; and the mixture is heated in a bath of mineral oil at a temperature of 115° C. A wine-red color develops almost instantly if cottonseed oil be present in the sample. The test will reveal the presence of as little as 1 per cent. of cottonseed oil in olive oil.

J. S. H.

Activities of the Reichsanstalt in 1920. (*Zeit. Instrumentenk.*, June, 1921.)—Among the manifold activities of the Charlottenburg institution the temperature coefficient of the resistance of pure metals received attention. Wire made from unusually pure nickel powder was found to have between 0° and 100° C. a coefficient of .0067, that is, when the temperature of the wire within this range was raised one degree its resistance increased by .0067 of its value at 0°. This is perhaps the largest result ever obtained in such a measurement with a pure metal. Small quantities of impurities affect the coefficient very differently according to their nature. Nickel with .3 per cent. cobalt, .1 per cent. iron and .05 per cent. silicon had a coefficient of .0063, not very different from that of pure nickel, while, on the other hand, specimens of nickel with .33 per cent. and .46 per cent. silicon respectively showed values of .0051 and .0048.

It was impossible to get cobalt wire of as great a degree of purity as in the case of nickel. The cobalt coefficient came out .0060 the highest value ever found for this metal.

In quite a diverse field the use of chromium leading-in wires has been investigated. Schott had called attention to the fact that the linear expansion coefficient of this metal is about the same as that of glass. Pure, commercial chromium could not, however, be made into wire. Heraeus in Hanau succeeded in producing a wire of chromium-nickel alloy of .3 to .4 mm. in diameter which works well when melted into lead glass. It carries from one-half to one ampere for long periods without detriment to the place of contact to the two materials.

G. F. S.

Contact Electricity. O. W. RICHARDSON. (*Science*, Sept. 30, 1921.)—For more than a century there has been a dispute as to the nature and cause of the difference of potential that manifects itself when two metals are put in contact. Volta himself in 1792 wrote "The metals . . . . can by themselves, and of their own proper virtue, excite and dislodge the electric field from its state of rest." In this opinion he has been supported by Davy, Helmholtz, and Lord Kelvin. The opposing view that in chemical action is to be sought the cause of the potential difference developed has received the adherence of Maxwell, Lodge and Ostwald.

Richardson's name always suggests to the physicist thermionic emission, that is the emission of ions and electrons by incandescent bodies. On superficial acquaintance there seems to be no connection between this phenomenon and contact electricity, but this would be a false conclusion. The author makes use of a study of what takes place within a portion of space severed from all communication with the rest of space—a method that yielded such good results in the matter of the pressure of radiation as well as elsewhere in the fields of physics. In such an enclosure there are two bodies, *A* and *B*, both hot enough to emit electrons, but *A* emits them faster than *B*. Thus *A* sends out more of the negatively charged electrons than it receives from *B*. It becomes positively charged, while *B* acquires a negative charge because it gains more electrons from *A* than it loses. Since the two bodies are oppositely charged they attract each other, and useful work may be done by letting them come together. It is a natural supposition that their contact will result in an equalization of potential. Let them be separated before the traffic in electrons can again establish opposite charges. After an interval such charges will again be in evidence and further work can be derived. By the continuance of this process all the heat energy will eventually be turned into useful work. Such a result is, however, in contradiction with the second law of thermodynamics. There must, therefore, be an error in the reasoning. One must choose between these horns of the dilemma, either the two bodies, *A* and *B*, must emit the same number of electrons or these two bodies are not discharged when they come into contact. Bodies do have different rates of emitting electrons. This is an experimental fact. The first alternative is accordingly ruled out and we are driven to accept the second. "It means that bodies have natural states of electrification whereby they become charged to definite potential differences whose magnitudes are independent of their relative positions. There is an intrinsic potential difference between *A* and *B* which is the same, at a given temperature, whether they are at a distance apart or in contact."

When the theory of the development of the potential difference is worked out this quantity is found to be a function of the absolute temperature and of the saturation current per unit area of the two bodies. Experiments made by Richardson show that a satisfactory agreement holds between the contact potential actually measured and that calculated from the formula derived theoretically.

Thus it seems possible that the long-standing dispute may be settled by an appeal to phenomena seemingly far afield from contact electricity.

G. F. S.

Problems in Physics. O. W. RICHARDSON. (*Science*, Sept. 30, 1921.)—"At the present time we have, I think, to accept it as a fact that the atoms consist of a positively charged nucleus of minute size, surrounded at a fair distance by the number of electrons requisite to maintain the structure electrically neutral. The nucleus contains all but about one two-thousandth of the mass of the atom, and its electrical charge is numerically equal to that of the negative electron multiplied by what is called the atomic number of the atom, the atomic number being the number which is obtained when the chemical elements are enumerated in the order of the atomic weights; thus, hydrogen = 1, helium = 2, lithium = 3, and so on. Consequently the number of external electrons in the atom is also equal to the atomic number. The diameters of the nuclei of the atoms are comparable with one-millionth of one-millionth part of a centimeter, and the problem of finding what lies within the interior of such a structure seems at first sight almost hopeless. It is to this problem that Rutherford has addressed himself by the direct method of bombarding the nuclei of the different atoms with the equally minute high-velocity helium nuclei (alpha-particles) given off by radioactive substances, and examining the tracks of any other particles which may be generated as a result of the impact. A careful and critical examination of the results shows that hydrogen nuclei are thus expelled from the nuclei of a number of atoms such as nitrogen and phosphorus. On the other hand, oxygen and carbon do not eject hydrogen under these circumstances, although there is evidence in the case of oxygen and nitrogen of the expulsion of other subnuclei whose precise structure is a matter for further inquiry. The artificial transmutation of the the chemical elements is thus an established fact. The natural transmutation has, of course, been familiar for some years to students of radioactivity. The philosopher's stone, one of the alleged chimeras of the mediæval chemists, is thus within our reach."

G. F. S.

The Mass Spectra of the Alkali Metals. F. W. ASTON. (*Phil. Mag.*, Sept., 1921.)—This is a continuation of one of the most splendid scientific campaigns ever undertaken. The objectives are no less than answers to these fundamental questions, "Why do certain elements have atomic weights that are integers?" "Why do other elements have atomic weights that are not whole numbers?" As element after element is examined by the methods of the positive rays, it is seen that those elements of integral atomic weight are not mixtures of elements but contain a single element, while those so-called elements of fractional atomic weight are made up of two or more elements, each of which has an integral atomic weight. The atomic weight of the mixture

depends on the proportions in which the constituent elements, the isotopes, are mixed in the ordinary chemical element.

To get positive rays of the alkali metals the anode in the discharge tube, a piece of platinum foil, was coated with a salt of the metal under investigation, and was heated by an electric current. For lithium the parabola method was used, but for the heavier metals the mass spectrograph was employed. The following table embodies the results:

Element	Atomic Number	Atomic Weight	Minimum No. of Isotopes	Mass of Isotopes in Order of Intensity
Lithium	3	6.94	2	7,6
Sodium	11	23.00	1	23
Potassium	19	39.10	2	39,41
Rubidium	37	85.45	2	85,87
Cæsium	55	132.81	1	133

"When this table is taken in connection with that of the elements given by the ordinary disharge-tube method, it will be seen that the mass-spectrum analysis of three groups of the periodic table—the halogens, the alkali metals, and the inactive gases—is now complete as far as the element cæsium; and with the possible exception of K(39) and the doubtful Cl(39) there are no isobares. The intermingling of the atomic weights so determined is very remarkable, and is particularly striking in the case of the ten consecutive integers representing the isotopes of bromine, krypton and rubidium—Kr, 78; Br, 79; Kr, 80; Br, 81; Kr, 82; Kr, 83; Kr, 84; Rb, 85; Kr, 86; Rb, 87. It is quite clear that the exact order of the chemical atomic weights has little significance and that the anomalies such as argon and potassium are merely due to the unequal relative proportions of their isotopic constituents."

G. F. S.

Reproductions of Manuscripts, Plates and Drawings Without a Camera.—*Le Procédé* gives an account of the procedure termed "Manul," which although patented some years ago, is just now attracting a good deal of attention in the technical journals. It is the invention of Max Ullman, who has made a partial anagram of his name as the title. *Le Procédé* claims that substantially the same principles were applied about 1890 by Yvon and more recently by Fontenay, the only important difference being that the French workers used gelato-bromide emulsions, while Ullman uses an egg albumin-bichromate film. The sensitive plate is placed in a frame provided with a glass front, the uncoated side of the plate being turned towards this glass. The document to be copied is placed with the text in contact with the sensitive surface, the frame closed and exposed to the light. Under these conditions, the light which passes

into the system is absorbed by the lines of the design, while it is reflected by the unprinted portions of the document; broadly speaking, it may be said that the amount of light acting on the sensitive surface where the high lights are, is double that which acts in the shadows. If, therefore, sufficient exposure is given, the high lights of the original will be, in the coating, completely insoluble, while the design will represent a somewhat soluble area. By development, a relief is produced from which copies can be obtained. The original patent does not give satisfactory details, but Aug. Albert, Professor at the Institute of Graphic Arts at Vienna, communicates to *Photographische Korrespondenz* some experiments on the procedure and claims to have obtained satisfactory results. The thick layer that results when ordinary gelatin bichromate mixtures are used is not applicable in the process, a very thin sensitive layer being necessary. Albert gives two formulas stating that both give good results. The sensitizing mixture should be spread by means of a roller, as it must be extremely thin and nearly colorless.

FORMULA I.

White of egg solution in water	25 c.c
Clarified liquid glue	20 c.c
Twenty per cent. solution of potassium bichromate	20 c.c

Mix thoroughly.

The white of egg should be beaten to a foam and then filtered. The glue solution is the same used in enamel work.

FORMULA II.

Water	60 c.c
Liquid glue	30 c.c
Ten per cent. sol. ammonium bichromate	24 c.c
Pure sugar (12.5 per cent. solution)	20 c.c

Mix thoroughly as before and add a few drops of glycerin. The materials used are not as clearly defined as they should be, but it is evident that the basis of one mixture is an albumin solution reinforced by gelatin, and that the commercial egg albumin and a high-grade gelatin can be used. In such case, a 14 per cent. solution should be used. The albumin should be in fine powder and dissolved in cold water. The other mixture relies practically on gelatin and sugar, thus being substantially the gum bichromate method. The main point in the process is to secure a thin and very transparent film.

The duration of exposure is a serious difficulty, and it is recommended to use a very strong light of constant power. It is likely that a number of trials will be required before any exactness can be obtained. The development should be in cold or at most very slightly warmed water. After this is completed, the plate is immersed in a

solution of fuchsin or some similar color, then into a yellow color (chrysoidin is recommended) in order to get a strong and non-actinic tint. After a short rinsing, the negative is used in the usual way for copying on metal.

In this connection, attention may be called to a process of copying without a camera, described and illustrated by Dr. Henry Leffmann at a lecture before The Franklin Institute and published in the JOURNAL OF THE FRANKLIN INSTITUTE, vol. 178 (1914), p. 743. This consisted simply in placing the sheet to be copied upon a glass plate that had been coated with luminous paint, the paint having been strongly activated by exposure to strong light. Upon the original sheet, a sensitive plate, film or development paper was placed and the luminous surface allowed to act for about ten minutes. Of course, the arrangement must be made in the dark and care taken that the sensitive surface is not exposed to the luminous one, except through the subject to be copied. For copying short letters or diagrams written only on one side of the paper the process is satisfactory. It will not answer for copying from papers containing matter on both sides as there will be confusion, but that objection seems to apply al o to the process above described. H. L.

Air Seasoning of Wood.—In coöperation with the sawmills and wood utilization plants throughout the country, the Forest Products Laboratory, Madison, Wisconsin, is organizing an extensive field study on the air seasoning of wood. This study, it is believed, will be of extreme interest to the lumber manufacturer and to the wood-using industries. The purpose is to determine the piling practice which will result in the fastest drying rates consistent with the least depreciation of stock, the least amount of required yard space, and the least handling costs. The study will be carried on concurrently on both hardwoods and softwoods. All the important commercial woods of the United States will eventually receive consideration.

The air seasoning of wood is an old practice. No systematic attempt has ever been made, however, to work out the exact conditions under which drying time and drying costs can be reduced to a minimum. It is not actually known which of the numberless methods of piling will give the quickest and the cheapest results under given climatic conditions. The new project will furnish a comparison of the effects of such piling variables as sticker heights, the spacings of boards in layers, the heights of pile foundations, and the directions of piling with relation to prevailing winds and yard alleyways.

The study is expected to decide whether from a business standpoint lumber should be dried partly at the mill and partly at the plant of utilization, or whether it should be completely dried at the mill. The data collected will also go a long way toward showing whether air seasoning or kiln drying is the more profitable.

A tentative working plan of the air seasoning study has been prepared by the Forest Products Laboratory, and copies are being

sent to the secretaries of the various lumber and wood-using associations, state foresters, forest school heads, and others eminently qualified to comment on the plan.

Coöperation in the air seasoning study is being offered on every side. As yet the plants at which the work will actually be done have not been definitely chosen, but the extreme interest already manifested indicates that there will be no difficulty in securing coöperation with plants ideal for the study. Actual field work will soon be well under way.

Present-day Shipping Problems.—In the presidential address of Sir William Joseph Noble, before the Northeast Coast Institution of Engineers and Ship-builders some of the problems of sea power were discussed, of course, from the British point of view. At the beginning of the war, the world's gross steam tonnage was 42½ tons, of which that of the United Kingdom represented nearly half in figures, but a larger proportion when efficiency was taken into full account About two-thirds of the British tonnage was less than fourteen years old, thus having the advantage in size and type. As a result half of the world's sea-borne trade was carried under the British flag, all other nations being more or less dependent thereon. During the war British tonnage decreased over 13 per cent. in the gross, but the actual reduction was larger, as the heaviest losses were among the largest ships. To-day the British tonnage represents but a little over one-third of the total, due in the main to the enormous expansion of the ship construction of the United States, which since 1914 has increased 570 per cent. France and Japan have also increased materially their merchant power.

"We must not lose sight of the fact that the war impressed on the other maritime nations the importance of merchant fleets, and they are making great efforts to establish large mercantile marines. Competition before the war was growing keener year by year, but it was comparatively small compared with the competition we shall have to face in the future. Japan in the East and the United States in the West are making strenuous efforts to retain some of the trades we lost to them during the war, and the friendly rivalry of these two Powers, added to the competition of our European neighbors, provides a task worthy of all our energies.

"Nothing but real peace will restore the security and the confidence we need. As one has pithily said—'There will be no peace of plenty until we have plenty of peace.' And we can have no assurance of peace so long as the governments of the world devote 20 per cent. of their expenditure to the maintenance of armaments and to preparations for war. To-day out of every

pound that we pay in taxes more than 12/- is spent on old and new wars. Before the war the U.S.A., Great Britain, France, Italy and Belgium together spent on armaments 228 millions sterling. After the war—with an impoverished world—the same countries are spending 1178 millions. Bankruptcy threatens most of the governments of the world, and it can only be averted by stopping this mad competition in armaments.

"My complaint about democracy is that it fails to face the economic basis of industry, it does not want to think things out to their logical conclusion and as a consequence endeavours to escape every shadow of discipline and personal obligation, seeking only material enjoyment, the things of the body and ignoring the things of the spirit."

H. L.

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TRANSMISSION CHARACTERISTICS OF THE SUBMARINE CABLE.*

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I.

THE transmission characteristics of a conducting system, such as a submarine cable circuit, are determined by its propagation constant, Γ, and characteristic impedance, K, which may be calculated for the frequency $p/2\pi$ from the formulas:

$$\Gamma = \sqrt{(R+ipL)\ (G+ipC)}, \tag{1}$$

$$K = \sqrt{\frac{R+ipL}{G+ipC}},$$

where R, L, G and C are the four fundamental line parameters, resistance, inductance, leakance, and capacity, all per unit length. These formulas are rigorous for all types of transmission systems; but the determination of the line parameters is not always possible by elementary methods, and may indeed be a matter of considerable complexity and involve rather difficult analysis. In the case of the submarine cable, exact formulas are available for calculating the capacity and leakage and the core impedance. Considerable uncertainty is introduced into the theory, however, on

* Communicated by Col. John J. Carty, D.Eng., Associate Editor.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

account of the lack of a method of determining the "return impedance," that is, the contribution of the "sea return" (sea water, armor wires, etc.) to the effective resistance and inductance of the circuit. An investigation of this problem was undertaken by the writers in connection with the research program of the American Telephone and Telegraph Company and the Western Electric Company.

The purpose of the present paper is to discuss transmission over the submarine cable, and, more particularly, to develop rigorous formulas for the calculation of the impedance of the return conductor of the cable. The results of theoretical calculations are then compared with actual experimental data; and the agreement between theory and experiment is so satisfactory as to indicate that the former is a reliable guide in the design and predetermination of the cable.

Besides providing a method for accurately calculating the transmission characteristics of a submarine cable, the present analysis leads to the following general conclusions:

(1) Contrary to usual assumption, the "sea return" impedance is by no means negligible. Even at quite moderate frequencies there is a considerable crowding of the return current into the immediate neighborhood of the cable, with a consequent rapid increase of the resistance and a corresponding decrease of the inductance of the circuit. Except at the lowest frequencies, therefore, the impedance of the "sea return" is a very important factor.

(2) The armor wires which surround the cable, and which are necessary for mechanical protection, have a very pronounced effect on the impedance of the sea return, and even at moderate frequencies may become the controlling factor. Their action is to screen the current from the sea water itself, and, as the frequency increases, to carry more and more of the return current, until it is almost entirely confined to the armor wires and excluded from the sea water.

(3) The rapid increase in the impedance of the armor wires with frequency, and their pronounced and even controlling effect on transmission makes a thorough-going study of their role in the electrical system a matter of first-class importance. Heretofore they appear to have been regarded only as a mechanical protection, and their effect on transmission has been ignored. The accurate

method of calculating their impedance which is developed in the following pages is believed to have considerable value in this connection.

(4) At relatively high frequencies, the return impedance, and hence the attenuation and the distortion, may be very greatly decreased by a correctly designed thin metallic sheath concentric with the core, and in electrical contact with the armor wires. The very important action of such a sheath, even when extremely thin, does not appear to have been adequately recognized or studied. It is suggested that the introduction of such a sheath affords a means of greatly increasing the range of frequencies which the cable can transmit.

The general problem of determining the transmission characteristics of a system consisting of an insulated conductor surrounded by a concentric ring of armor wires immersed in sea water is of considerable difficulty, since in this case the propagated wave must be represented as a set of component waves centered upon or diverging from the axes of the core and of the individual armor wires. The problem was first simplified by replacing the ring of armor wires by a cylindrical sheath, thus giving circular symmetry to the the structure. The analysis of this case, however, showed that the effect of the iron sheath replacing the armor wires was so pronounced as to make this simplifying assumption of doubtful validity. The general problem was therefore attacked, and rigorous methods developed for calculating the effect of the armor wires upon transmission. The results in this case differ markedly from those obtained for the case of a continuous iron sheath, which indicates that great caution must be used in making assumptions regarding the physical structure of the armoring.

The present paper follows rather closely the course of the writers' investigation. In Section II is analyzed the problem of transmission over a system consisting of n coaxial cylindrical conductors, which may be either in electrical contact at their adjacent surfaces or separated from each other by dielectric spaces. The outermost conductor, consisting of the sea water, is assumed to extend to infinity. This analysis is then applied, in Section III, to the case of a submarine cable which is armored with a continuous iron sheath. This problem is not only of interest in itself, but serves as a first approximation to the case of

an actual cable, and gives a clear qualitative idea of the effect of the various factors on transmission. In Section IV the problem of the submarine cable armored with a ring of iron wires is attacked and solved by rigorous methods, and the theoretical results are then compared with experimental data.

II.

The solution of the problem of transmission of periodic currents over a system comprising n coaxial cylindrical conductors consists in finding the particular solution of Maxwell's equations which satisfies the boundary conditions—continuity of tangential and magnetic forces at the surfaces of the conductors. Let the common axis of the conductors coincide with the Z axis of a system of polar coördinates, R, Φ, Z, and let the electric and magnetic variables involve the common factor $exp(-\Gamma z+ipt)$. Γ is therefore the propagation factor characterizing transmission, and p is 2π times the frequency. This factor will not be explicitly written in any of the work that follows, but it will be assumed to be incorporated in each of the electric variables so that

$$\frac{\partial^n}{\partial z^n}=(-\Gamma)^n, \qquad \frac{\partial^n}{\partial t^n}=(ip)^n.$$

From symmetry, it is evident that the component of electric field intensity in the direction of ϕ vanishes, and that the magnetic lines of force are circles lying in planes perpendicular to the axis of the system, and centered on that axis. Also, the axial and radial electric forces are independent of ϕ. It can be shown that the radial component of electric field intensity *in the conductors* is negligibly small compared with the axial component. The latter, for a given conductor, is of the form $E\, exp(-\Gamma z+ipt)$, where E is a solution of the differential equation

$$\frac{\partial^2 E}{\partial r^2}+\frac{1}{r}\frac{\partial E}{\partial r}+(\Gamma^2-4\pi\lambda\mu ip)E=0. \tag{2}$$

Here λ and μ are the electrical conductivity and the magnetic permeability of the particular conductor, measured in absolute electromagnetic units, and E is a function of r alone.

For the frequencies in which we are interested it may be show that $\Gamma^2/4\pi\lambda\mu p$ is exceedingly small, so that (2) may be written

$$\frac{\partial^2 E}{\partial r^2} + \frac{1}{r}\frac{\partial E}{\partial r} - 4\pi\lambda\mu i p E = 0. \qquad (3)$$

We will designate by the subscript j all quantities pertaining to the j^{th} conductor, counting from the axis. The solution of (3) for this conductor may then be written

$$E_j = A_j J_o(\rho_j) + B_j K_o(\rho_j), \qquad (4)$$

where J_o and K_o are Bessel functions of zero order, A_j and B_j are arbitrary constants and

$$\rho_j = ri\sqrt{4\pi\lambda_j\mu_j p i} = r\alpha_j .$$

The magnetic field intensity can then be obtained from the curl law,

$$\mu\frac{dH}{dt} = \frac{dE}{dr},$$

which gives

$$H_j = \frac{\alpha_j}{\mu_j i p}\left[A_j J_o'(\rho_j) + B_j K_o'(\rho_j)\right], \qquad (5)$$

where the prime indicates differentiation with respect to ρ_j. Taking the line integral of both sides of (5) around circular paths in conductor j lying close to the inner and outer surfaces of the cylinder we obtain

$$A_j J_o'(y_j) + B_j K_o'(y_j) = \frac{2\mu_j i p}{y_j}(I_1 + I_2 + \cdots + I_{j-1}), \qquad (6)$$

$$A_j J_o'(x_j) + B_j K_o'(x_j) = \frac{2\mu_j i p}{x_j}(I_1 + I_2 + \cdots + I_j),$$

in which

I_j = current in the jth conductor,

$x_j = \alpha_j a_j$,

$y_j = \alpha_j b_j$,

a_j = external radius of jth conductor,

b_j = internal radius of jth conductor.

The values of the electric field intensity at the inner and outer surfaces of the j^{th} conductor can be written, from (4)

$$E_j' = A_j J_o(y_j) + B_j K_o(y_j),$$
$$E_j'' = A_j J_o(x_j) + B_j K_o(x_j).$$

Combining, in turn, each of these equations with relations (6) to eliminate A_j and B_j, we obtain

$$\begin{aligned} E_j' &= Z_{j1}' I_1 + Z_{j2}' I_2 + \cdots + Z_{jj}' I_j \\ E_j'' &= Z_{j1}'' I_1 + Z_{j2}'' I_2 + \cdots + Z_{jj}'' I_j, \end{aligned} \tag{7}$$

in which

$$\begin{aligned} Z_{jk}'' = 2\mu_j i p \Bigg[& \frac{1}{x_j} \frac{J_0(x_j) K_0'(y_j) - J_0'(y_j) K_0(x_j)}{J_0'(x_j) K_0'(y_j) - J'(y_j) K_0'(x_j)} \\ & - \frac{1}{y_j} \frac{J_0(x_j) K_0'(x_j) - J_0'(x_j) K_0(x_j)}{J_0'(x_j) K_0'(y_j) - J_0'(y_j) K_0'(x_j)} \Bigg], \quad k \neq j \\ Z_{jj}'' = \frac{2\mu_j i p}{x_j} & \left[\frac{J_0(x_j) K_0'(y_j) - J_0'(y_j) K_0(x_j)}{J_0'(x_j) K_0'(y_j) - J_0'(y_j) K_0'(x_j)} \right], \\ Z_{jk}' = 2\mu_j i p \Bigg[& \frac{1}{x_j} \frac{J_0(y_j) K_0'(y_j) - J_0'(y_j) K_0(y_j)}{J_0'(x_j) K_0'(y_j) - J_0'(y_j) K_0'(x_j)} \\ & - \frac{1}{y_j} \frac{J_0(y_j) K_0'(x_j) - J_0'(x_j) K_0(y_j)}{J_0'(x_j) K_0'(y_j) - J_0'(y_j) K_0'(x_j)} \Bigg], \quad k \neq j \\ Z_{jj}' = \frac{2\mu_j i p}{x_j} & \left[\frac{J_0(y_j) K_0'(y_j) - J_0'(y_j) K_0(y_j)}{J_0'(x_j) K_0'(y_j) - J_0'(y_j) K_0'(x_j)} \right]. \end{aligned} \tag{8}$$

We have now succeeded in expressing the electric forces in the conductors as linear functions of the currents $I_1 \ldots I_n$, the coefficients being of the nature of impedances, by a method which is simply an application of the principle of continuity of magnetic field intensity. The remaining boundary condition, continuity of the tangential component of electrical field intensity gives, where two consecutive cylinders are in electrical contact,

$$E_{j+1}' - E_j'' = \left[Z_{j+1,1}' - Z_{j,1}'' \right] I_1 + \cdots + \left[Z_{j+1,j}' - Z_{j,j}'' \right] I_j + Z_{j+1,j+1}' I_{j+1} = 0. \tag{9}$$

This gives m relations between the n currents of the system, m being the number of contacts between successive cylinders. In the case where the j and $(j+1)$st conductors are separated by a layer of dielectric material, a relation between the boundary values of electric field intensity may be obtained as follows:

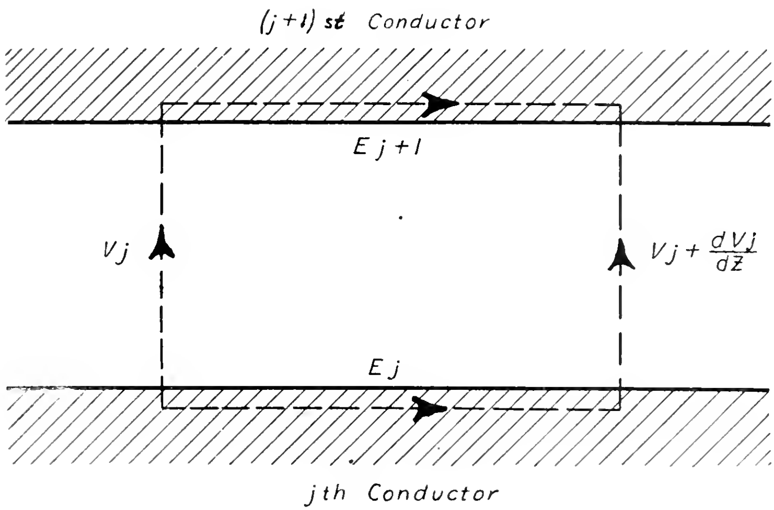
If E_r is the radial electric field intensity in the dielectric, then

$$V_j = \int_{a_j}^{b_{j+1}} E_r \, dr$$

is the potential difference between the j and $(j+1)$st conductors, in the sense employed in ordinary circuit theory. If we now apply the law

$$\text{curl } E = -\mu \frac{dH}{dt}$$

FIG. 1.



to the elementary contour shown in Fig. 1 we get

$$-\frac{\partial V_j}{\partial z} + E'_{j+1} - E''_j = \mu i p \Phi_j, \tag{10}$$

or

$$\Gamma V_j + E'_{j+1} - E''_j = \mu i p \Phi \tag{11}$$

where Φ_j is the magnetic flux threading the contour and is given by

$$\Phi_j = 2(I_1 + I_2 + \cdots + I_j)\log\frac{b_{j+1}}{a_j}.$$

From the law

$$\text{div } kE = 4\pi Q\,,$$

$$E_r = \frac{2}{k_j r}(Q_1 + Q_2 + \cdots + Q_j)$$

where Q_j is the charge on the j^{th} conductor and k_j is the dielectric constant of the medium, whence,

$$V_j = \frac{2}{k_j} \log \frac{b_{j+1}}{a_j} (Q_1+Q_2+\cdots+Q_j). \tag{12}$$

Furthermore, the rate of gain of charge is

$$\frac{\partial}{\partial t}(Q_1+Q_2+\cdots+Q_j) = -\frac{\partial}{\partial z}(I_1+I_2+\cdots+I_j) - 4\pi(Q_1+Q_2+\cdots+Q_j)g_j/k_j, \tag{13}$$

where the last term represents the leakage current, g_j being the specific conductivity of the dielectric.

From (13) we have

$$\frac{1}{k_j}(4\pi g_j + ipk_j)(Q_1+Q_2+\cdots+Q_j) = \Gamma(I_1+I_2+\cdots+I_j,)$$

and substituting this value of $(Q_1+Q_2+\ldots+Q_j)$ in (12) gives

$$V_j = 2(I_1+I_2+\cdots+I_j)\frac{\Gamma}{4\pi g_j + ipk_j} \log \frac{b_{j+1}}{a_j}; \tag{14}$$

and from this and (11)

$$-\left[\frac{\Gamma^2}{G_j+ipC_j} - ipL_j\right](I_1+I_2+\cdots+I_j) = E'_{j+1} - E''_j \tag{15}$$

where $$G_j = \frac{4\pi g_j}{2\log\frac{b_{j+1}}{a_j}} \qquad C_j = \frac{k_j}{2\log\frac{b_{j+1}}{a_j}} \qquad L_j = 2\mu_j \log \frac{b_{j+1}}{a_j}.$$

Subtituting the values of E''_j and E'_{j+1} from (7) in (15) gives

$$-\left[\frac{\Gamma^2}{G_j+ipC_j} - ipL_j\right](I_1+I_2+\cdots+I_j) = (Z'_{j+1,1} - Z''_{j,1})I_1 + \cdots$$
$$+Z'_{j+1,j+1}I_{j+1}. \tag{16}$$

An equation of this sort may be obtained for each layer of dielectric, and these combined with equations (9) and the condition that the electric field intensity in the sea water must vanish at infinity,

$$E'_n = Z''_{n1}I_1 + \cdots + Z''_{nn}I_n = 0,$$

given n relations between $I_1 \ldots I_n$. In order that these shall be consistent, the determinant of the coefficients must vanish.

$$\begin{vmatrix} Z'_{21}-Z''_{11}, & Z'_{22}, & 0 & --- & 0 \\ Z'_{31}-Z''_{21}, & Z'_{32}-Z''_{22}, & Z'_{33}, & --- & 0 \\ - & - & - & --- & - \\ Z'_{j+1,1}-Z''_{j,1}+Z_j, & Z'_{j+1,2}-Z''_{j,2}+Z_j, & - & --- & - \\ - & - & - & --- & - \\ Z''_{n1}, & Z''_{n2}, & - & --- & Z''_{nn} \end{vmatrix} = 0 \tag{17}$$

where

$$Z_j = \frac{\Gamma^2}{G_j + ipC_j} - ipL_j \,.$$

This is an equation in Γ^2 of degree equal to the number of dielectric layers, consequently, there are as many independent modes of propagation in the system as there are branches in the network of conductors.

From this point the method of determining the behavior of the system depends upon conditions in the particular problem. For the case where there are k dielectric layers separating the conductors into $k+1$ groups the current on the j^{th} group may be written in the form

$$I_j = A_{j1}\, exp\,(-\Gamma_1 z + ipt) + \cdots + A_{jk}\, exp\,(-\Gamma_k z + ipt)$$
$$+ B_{j1}\, exp(\Gamma_1 z + ipt) + \cdots + B_{jk}\, exp(\Gamma_k z + ipt),$$

where $\Gamma_1^2 \ldots \Gamma_k^2$ are the k roots of the determinant (17) and $A_{j1} \ldots A_{jk}$, $B_{j1} \ldots B_{jk}$ are constants. These constants are not all independent, however, since, for each value of Γ, Γ_1 for instance, there exist k relations of the form (16) which the corresponding set of constants A_{11}, A_{21}, ... A_{k1} must satisfy. The remaining $2k$ independent constants can then be determined from a knowledge of the conditions at the terminals of the conductors.

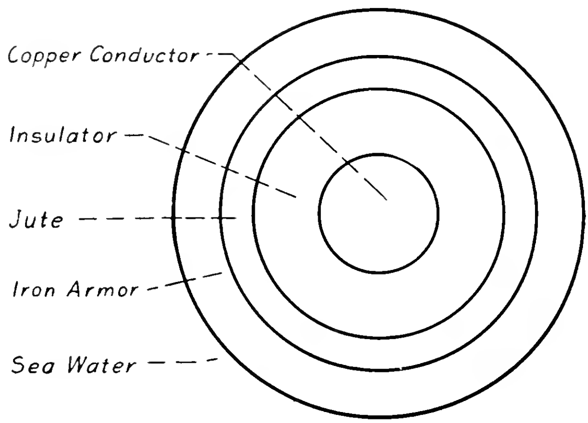
It is important to observe that the transmission characteristics of a system of coaxial conductors are influenced to a great extent by the manner of connecting the various members of the system. Anomalies in the impedance of a complicated network

such as a submarine cable with several conducting sheaths in the return path, may often be traced to lack of proper connections between the sheaths, or to faulty joints.

III.

The submarine cable armored with a continuous coaxial sheath, as shown in Fig. 2, is a particular case of the foregoing, and one which presents a clearer idea of the physical significance of the various steps in the general theory. There are only two

FIG. 2.



groups of conductors, the first consisting of the core conductor, and the second comprising the iron sheath and the sea water, the two groups being separated by the insulating material and the layer of jute. Consequently, there is only one mode of propagation, and the analysis is considerably simplified.

The jute is assumed to contain sufficient sea water so that although it conducts practically no current axially, it maintains equality of potential between the outer surface of the gutta percha and the inner surface of the iron sheath. Consequently equation (10) may be written

$$\frac{\partial V}{\partial z} - E_2' + E_1'' = -\mu i p \Phi = -i p L_{12} I_1, \tag{18}$$

where E''_1 and E'_2 are the values of electric field intensity at the outer surface of the core conductor and the inner surface of the iron, respectively, V is the potential difference between these two

surfaces, and Φ is the magnetic flux threading unit length of the gutta percha and jute. Also, from (14)

$$-\frac{\partial V}{\partial z}=\frac{\Gamma^2}{G+ipC}I_1 \tag{19}$$

in which I_1 is the current in the core and

$$G=\frac{4\pi g_{12}}{2\log\frac{b}{a_1}}, \qquad C=\frac{k_{12}}{2\log\frac{b}{a_1}}, \tag{20}$$

where g_{12} and k_{12} are the electrical constants of the gutta percha, and b is the external radius of the core. It is evident, that G and C are respectively the leakage and capacity of unit length of the cable. Therefore, from (1),

$$\frac{\Gamma^2}{G+ipC}=R+ipL=Z, \tag{21}$$

where R and L are the resistance and induction of unit length of the cable, including the sea return. Equation (18) may then be written

$$Z\,I_1=E''_1-E'_2+ipL_{12}I_1. \tag{22}$$

To determine Z we must express E''_1 and E'_2 as functions of I_1.

We have seen that

$$E''_1=Z_1 I_1, \tag{23}$$

where Z_1 may be termed the "internal impedance" per unit length of this conductor. In fact, when we place $y_1=o$ in (8) we obtain

$$Z''_{11}=\frac{2u_1 ip}{x_1}\,\frac{J_0(x_1)}{J'_0(x_1)}, \tag{24}$$

which is the usual formula for the internal impedance of a cylindrical conductor.

Similarly

$$E'_2=-Z_2 I_1 \tag{25}$$

where Z_2 is the internal impedance of the return conductor, the minus sign being due to the fact that the current in the return is in the negative direction of z.

Inserting (23) and (25) in (22) gives

$$Z=Z_1+Z_2+ipL_{12}.$$

The quantity Z_2 may be determined in the following manner. From (7) we have

$$E_2' = Z_{21}' I_1 + Z_{22}' I_2, \tag{26}$$

where I_2 is the current in the iron sheath. The value of this current can be found by applying the condition of continuity of electric field intensity at the common surface of the iron and the sea water, as in equation (9). This gives

$$Z_{21}'' I_1 + Z_{22}'' I_2 = Z_{31}' I_1 + Z_{32}' I_2 + Z_{33}' I_3,$$

in which I_3 is the current in the sea water. From (8) it can be seen that $Z_{33} = O$, since $x_3 = \infty$, therefore

$$I_2 = \frac{Z_{31}' - Z_{21}''}{Z_{22}'' - Z_{32}'} I_1. \tag{27}$$

Substituting (27) in (26) gives

$$E_2' = \left[Z_{21}' + \frac{Z_{31}' - Z_{21}''}{Z_{22}'' - Z_{32}'} Z_{22}' \right] I_1,$$

and by comparison with (25) we have

$$Z_2 = -Z_{21}' - \frac{Z_{31}' - Z_{21}''}{Z_{22}'' - Z_{32}'} Z_{22}' \tag{28}$$

as the internal impedance of the return conductor. The resistance and reactance per unit length of this portion of the circuit are then represented by the real and imaginary parts of (28) respectively.

We may then determine R and L from the formula

$$Z = R + ipL = Z_1 + Z_2 + ipL_{12}, \tag{29}$$

where Z_1 and Z_2 are calculated from (23) and (28) and

$$L_{12} = 2 \log \frac{b_2}{a_1},$$

b_2 and a_1 being the inner radius of the iron and the outer radius of the core conductor, respectively.

For purposes of comparison, the return impedance is calculated for the case where the iron armoring is absent, the return current being conducted by the sea water alone. As in the preceding case,

$$Z_1 = \frac{2\mu_1 ip}{x_1} \frac{J_o(x_1)}{J'_o(x_1)}.$$

The expression for Z_2 simplifies considerably. The electric field intensity in the sea water may be written, from (4),

$$E_2 = B_2 K_o(\rho_2), \tag{30}$$

the term in J_o being absent in order to permit E_2 to vanish at infinity.

Also, from (6),

$$B_2 K'_o(y_2) = \frac{2\mu_2 ip}{y_2} I_1. \tag{31}$$

From (30) and (31) we have

$$E'_2 = \frac{2\mu_2 ip}{y_2} \frac{K_o(y_2)}{K'_o(y_2)} I_1. \tag{32}$$

from which the return impedance can be written,

$$Z_2 = -\frac{2\mu_2 ip}{y_2} \frac{K_o(y_2)}{K'_o(y_2)}. \tag{33}$$

We have then

$$Z = R + ipL = \frac{2\mu_1 ip}{x_1} \frac{J_o(x_1)}{J'_o(x_1)} - \frac{2\mu_2 ip}{y_2} \frac{K_o(y_2)}{K'_o(y_2)} + ipL_{12}.$$

The resistance and inductance of the sea return of a submarine cable were calculated from formula (28), employing the following values for the constants:

$$\text{Copper} \quad \begin{cases} a_1 = .226 \text{ cm.} \\ b_1 = 0 \\ \mu_1 = 1 \\ \lambda_1 = 6.06 \times 10^{-4} \end{cases}$$

$$\text{Iron} \quad \begin{cases} a_2 = .990 \text{ cm.} \\ b_2 = .737 \text{ cm.} \\ \mu_2 = 100 \\ \lambda_2 = 8 \times 10^{-5} \end{cases}$$

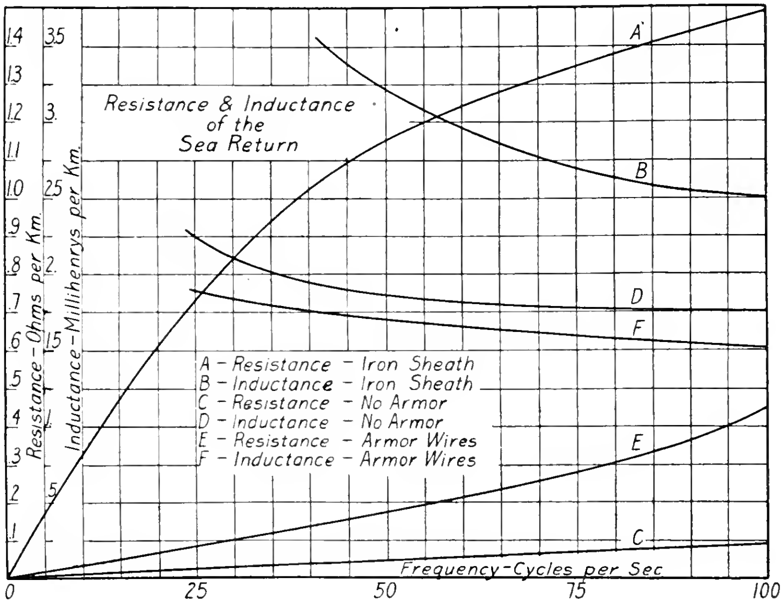
$$\text{Sea Water} \quad \begin{cases} a_3 = \infty \\ b_3 = .990 \text{ cm.} \\ \mu_3 = 1 \\ \lambda_3 = 5 \times 10^{-11} \end{cases}$$

The armoring was then assumed to be replaced by sea water, and the resistance and inductance of the cable were calculated from (33).

The results of the calculations are shown in the curves of Fig. 3.

It is evident from these curves that the effect of the iron armoring is to increase considerably the impedance of the return

FIG. 3.

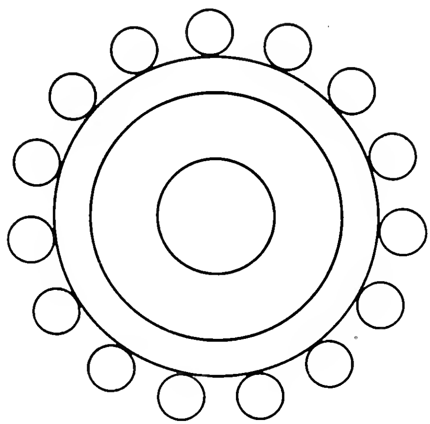


path. The physical explanation of this fact is that the iron acts as a shield to screen from the sea water the electromagnetic effects of the current flowing in the cable conductor. Energy is dissipated in the armoring and is prevented from spreading out through the surrounding medium. The assumption that the armor wires could be replaced by a solid cylinder of iron is, therefore, subject to question, since it is possible that the larger surface area of the assemblage of armor wires, and the gaps between these wires may be effective in diminishing the energy dissipated in the armoring and consequently diminishing the screening effect. This problem is investigated in the following section.

IV.

The physical system under consideration is shown schematically in cross-section in Fig. 4, and consists of an insulated conductor and protective covering of jute, surrounded by a ring of N armor wires immersed in sea water. The method of solution is essentially similar to that given in the preceding pages, and consists in determining the values of electric field intensity at the outer surface of the core conductor and the inner surface of the return conductor, from which the internal impedances of the two conductors can be found.

FIG. 4.



The main difficulty in the analysis is caused by the lack of uniaxial symmetry in the return conductor. This was overcome by employing a method developed by one of the authors [1] in a study of transmission in parallel wires.

The electric field intensity in the sea water satisfies the differential equation

$$\frac{\partial^2 E}{\partial r^2}+\frac{1}{r}\frac{\partial E}{\partial r}+\frac{1}{r^2}\frac{\partial^2 E}{\partial \phi^2}-4\pi\lambda\mu piE=0,$$

the solution of which is a Fourier-Bessel expansion,

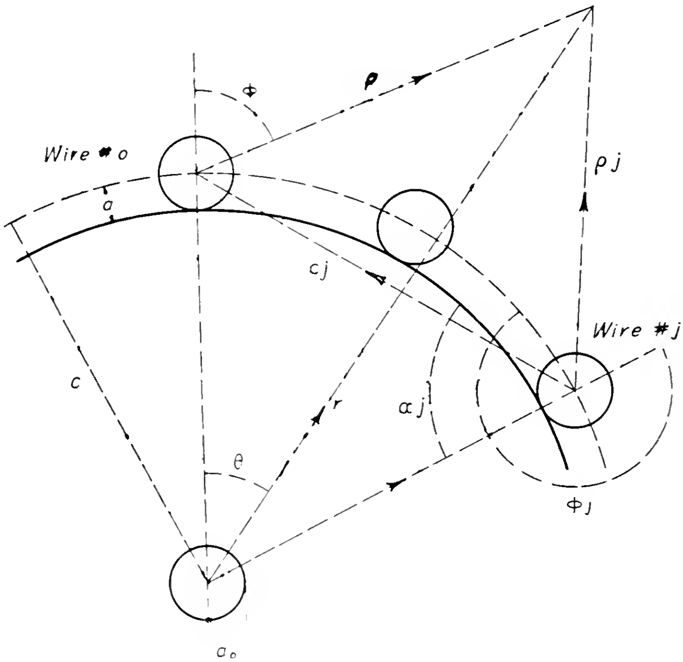
$$E=A_0K_0(r\alpha)+A_1K_1(r\alpha)\cos\phi+A_2K_2(r\alpha)\cos 2\phi+\cdots+,$$

r and ϕ being referred to the axis of the particular wire.

[1] "Wave Propagation over Parallel Wires; The Proximity Effect." John R. Carson, *Phil. Mag.*, vol. xli, p. 607 (1921).

Assuming that the current distribution in the core conductor is independent of the angle ϕ, that is, neglecting the individual character of the armor wires only in their effect on the current distribution in the core, the effect due to the current in the core is

FIG. 5.



represented by the first term of such a series, and the total field intensity may be written

$$E = AK_o(r\alpha) + \sum_{j=o}^{N-1} \sum_{s=o}^{\infty} B_s K_s(\alpha\rho_j) \cos s\phi_j, \tag{34}$$

ρ_j and ϕ_j being referred to the axis of wire j, as shown in Fig. 5. That is, the resultant field is expressible as a set of waves centered on the axis of the cable and the axes of the N armor wires.

In the neighborhood of the armor wires the arguments of the Bessel functions are sufficiently small [2] to permit of the approximations

[2] See Note I at end of paper.

$$K_o(\alpha\rho) = K - \log \rho,$$

where

$$K = 0.11593 \log \frac{1}{\alpha},$$

and

$$K_s(\alpha\rho) = \frac{1}{(-\alpha\rho)^s}.$$

The series (34) can, therefore, be written

$$E = A(K - \log r) + B_o(NK - \sum_{j=o}^{N-1} \log \rho_j) + \sum_{j=o}^{N-1} \sum_{s=1}^{\infty} B_s \frac{\cos(s\phi_j)}{\rho_j^s}, \tag{35}$$

in which B_s has absorbed the constant quantities. From this, the magnetic intensity in the sea water can be obtained by differentiation.

Inside any armor wire, at the surface, the field intensities are

$$E = C_o J_o(\xi) + C_1 J_1(\xi) \cos \phi + \cdots + C_n J_n(\xi) \cos n\phi + \cdots +, \tag{36}$$

$$H_\Phi = \frac{1}{aui p}\left[C_o J_o'(\xi) + C_1 J_1'(\xi) \cos\phi + \cdots + C_n J_n'(\xi) \cos n\phi + \cdots +\right], \tag{37}$$

where $\xi = ai\sqrt{4\pi\lambda\mu p i}$,

λ and μ being the electrical conductivity and the magnetic permeability, respectively, of the material of the armor wire. The quantities a and ϕ are centered on the axis of the wire.

In order to determine the coefficients A, B_o, B_1, –, C_o, C_1, – we make use of the fact that the electric and the magnetic field intensities are continuous at the surface of the wire. It is obvious, however, that nothing can be learned by equating (35) and (36) since they are formally dissimilar. We therefore transform[3] the various terms of (35) to a common axis which coincides with the axis of one of the armor wires, hereafter called wire "zero," and the electric field intensity in the sea water, close to the surface of the armor wire, is

$$E = (A + NB_o)K - A\log c - B_o\log(a.c_1.c_2\ldots c_{n-1}) - \Sigma_o$$

[3] See Note II.

$$+\left[q_1/\zeta-\zeta(A+S_{11}B_o)+\frac{\zeta}{1!}\Sigma_1\right]\cos\phi$$

$$+\left[q_2/\zeta^2+\frac{\zeta^2}{2}(A+S_{22}B_o)+\frac{\zeta^2}{2!}\Sigma_2\right]\cos 2\phi \qquad (38)$$

$$- - - - - - - - -$$

$$+\left[q_n/\zeta^n+\frac{(-\zeta)^n}{n}(A+S_{nn}B_o)-\frac{(-\zeta)^n}{n!}\Sigma_n\right]\cos n\phi,$$

where

$$\begin{aligned}
\Sigma_0 &= S_{11}q_1 - S_{22}q_2 + S_{33}q_3 \cdots,\\
\Sigma_1 &= S_{02}q_1 - 2S_{13}q_2 + 3S_{24}q_3 \cdots,\\
\Sigma_2 &= 1.2S_{13}q_1 - 2.3S_{04}q_2 + 3.4S_{15}q_3 \cdots,\\
\Sigma_3 &= 1.2.3S_{24}q_1 - 2.3.4S_{15}q_2 + 3.4.5S_{06}q_3 \cdots,\\
&- - - - - - - - - -
\end{aligned} \qquad (39)$$

$$S_{pq}=\sum_{j=1}^{N-1}\frac{\cos pa_j}{(2\sin\frac{j\pi}{n})q},$$

$$q_n=B_n/c^n, \qquad (40)$$

$$\zeta=\frac{a}{c}.$$

The quantities ϕ and a have the same significance as in equations (36) and (37).

The tangential magnetic field intensity in the sea water at the surface of wire "zero" is, therefore,

$$H_\Phi=\frac{1}{ip}\frac{dE_z}{da}=\frac{1}{ipa}\Bigg[-B_o+\cos\phi\left[-q_1/\zeta-\zeta(A+S_{11}B_o)+\frac{\zeta}{1!}\Sigma_1\right] \qquad (41)$$

$$+2\cos 2\phi\left[-q_2/\zeta^2+\frac{\zeta^2}{2}(A+S_{22}B_o)-\frac{\zeta^2}{2!}\Sigma_2\right]$$

$$- - - - - - - - - -$$

$$+n\cos n\phi\left[-q_n/\zeta^n+\frac{(-\zeta)^n}{n}(A+S_{nn}B_o)-\frac{(-\zeta)^n}{n!}\Sigma_n\right]- - -\Bigg].$$

To satisfy the condition of continuity of electric and magnetic field intensities at the surface of the armor wire it is necessary that the coefficients of the corresponding terms of (36) and (38) and of (37) and (41) to be equal. This gives

$$C_o J_o(\xi) = (A + NB_o)K - A\log c - B_o \log(a.c_1 \ldots c_n) - \Sigma_o \ , \tag{42}$$

$$C_n J_n(\xi) = q_n/\zeta^n + \frac{(-\zeta)^n}{n}(A + S_{nn}B_o) - \frac{(-\zeta)^n}{n!}\Sigma_n \ , \ n = 1 - - \infty \tag{43}$$

$$\xi J'_o(\xi) C_o = -\mu B_o \ , \tag{44}$$

$$\xi J'_n(\xi) C_n = -n\mu \left[q_n/\zeta^n - \frac{(-\zeta)^n}{n}(A + S_{nn}B_o) - \frac{(-\zeta)^n}{n!}\Sigma_n \right] . \ n = 1 - - \infty . \tag{45}$$

From these expressions the quantities $B_1 \ldots C_1 \ldots$ can be determined. Multiplying (43) by $n\mu$ and subtracting (45) gives

$$C_n = \frac{2n\mu q_n}{\zeta^n} \frac{1}{n\mu J_n(\xi) - \xi J'_n(\xi)} , \tag{46}$$

which expresses C_n in terms of q_n. Multiplying (43) by $\zeta J'_n(\zeta)$ and (45) by $J_n(\zeta)$, and subtracting gives

$$q_n = (-1)^n \lambda_n \zeta^{2n} \left[\frac{1}{n}(A + S_{nn}B_o) - \frac{1}{n!}\Sigma_n \right] , n = 1 - - \infty \tag{47}$$

where

$$\lambda_n = \frac{n\mu J_n(\xi) - \xi J'_n(\xi)}{n\mu J_n(\xi) + \xi J'_n(\xi)} . \tag{48}$$

From the infinite set of simultaneous equations (47) the infinitely many varieties q_n may be determined in terms of A and B_o.[4]

We have thus determined the arbitrary constants $C_o \ldots C_n$ and $q_1 \ldots q_n$ (or $B_1 \ldots B_n$) as functions of A and B_o. It remains to express the latter quantities in terms of physical quantities. If I_1 is the

[4] See Note III.

current in the armor then $\frac{I_1}{N}$ is the current in a single wire. Integrating (41) completely around the armor wire "zero" gives, therefore,

$$2pi\frac{I_1}{N} = -B_o \,. \tag{49}$$

Similarly, if I_o is the current in the core conductor, we find

$$2piI_o = -A \,. \tag{50}$$

We can, therefore, express all the arbitrary constants as linear, homogeneous functions of I_o and I_1.

To determine the relation between these currents, we have from (42) and (44),

$$CJ_o(\xi) = \frac{ZI_1}{N} \,, \tag{51}$$

where

$$Z = \frac{2uip}{\xi}\,\frac{J_o(\xi)}{J_o'(\xi)} \,.$$

Substituting (49), (50) and (51) in (42) gives

$$\frac{Z}{N}I_1 = -2ip\,(I_o+I_1)K + 2ipI_o\log c + 2ip\frac{I_1}{N}\log\,(a.c_1\ldots c_n) \tag{52}$$

$$-(S_{11}\,q_1 - S_{22}\,q_2 + S_{33}\,q_3 - \ldots),$$

from which, since $q_1 \ldots q_n$ are functions of I_1 and I_o, the ratio I_o/I_1 can be obtained.

Having shown that the constants A, B_o ... of the series (35) are proportional to I_o, we can express the electric field intensity at the inner surface of the return conductor in the form

$$E_2 = -Z_2 I_o \,.$$

The computation of Z_2 is facilitated by transforming the terms of (35) to the axis of the core conductor [5] and placing $r = c - a$. We thus obtain

$$E_2 = -Z_2\,I_o = (A + NB_o)K - A\log(c-a) - NB_o\log c - N(q_1 - q_2 + q_3 - -)$$

$$+ (\text{terms containing } \cos\theta,\ \cos 2\theta, \text{ etc., as factors}). \tag{53}$$

[5] See Note II.

We have, by applying the curl law to an elementary contour which links the core conductor and the return,

$$\frac{\partial V}{\partial z} - E_1 + E_2 = -ip\Phi_{12}, \tag{54}$$

where

$$E_1 = Z_1 I_0 = \frac{2\mu_0 ip}{\xi_0} \frac{J_0(\xi_0)}{J_0'(\xi_0)} I_0,$$

$$\Phi_{12} = L_{12} I_0 = 2I_0 \log \frac{c-a}{a_0}, \tag{55}$$

and

$$\xi_0 = a_0 i\sqrt{4\pi\lambda_0\mu_0 ip},$$

λ_0 and μ_0 being the electrical constants of the core conductor and a_0 its radius. The value given above for Φ_{12} holds only for the contour on which E_2 is independent of the angle θ, that is, when the terms of (53) that contain cos θ, cos 2θ, etc., vanish. The value of Z_2 to be used in (54) is therefore determined from

$$E_2 = -Z_2 I_0 = (A + NB_0)K - A \log(c-a) - NB_0 \log c - N(q_1 - q_2 +). \tag{56}$$

As before,

$$-\frac{\partial V}{\partial z} = (R + ipL)I_0, \tag{57}$$

where R and L are the resistance and inductance per unit length of the cable, including the sea return.

We have then from (54),

$$R + ipL = Z_1 + Z_2 + ipL_{12}, \tag{58}$$

from which R and L can be determined.

The process of calculating the resistance and inductance of a submarine cable by the method just described may be summarized as follows:

(1) Determine from (47) the quantities $q_1 \dots q_n$ in terms of A and B_0, and then in terms of I_1 and I_0 by (49) and (50).

(2) Substitute these values of $q_1 \dots q_n$ in (52) and obtain the ratio I_0/I_1.

(3) Substitute for A, B_0 and $q_1 \dots q_n$ in (56) their values in terms of I_0 and I_1.

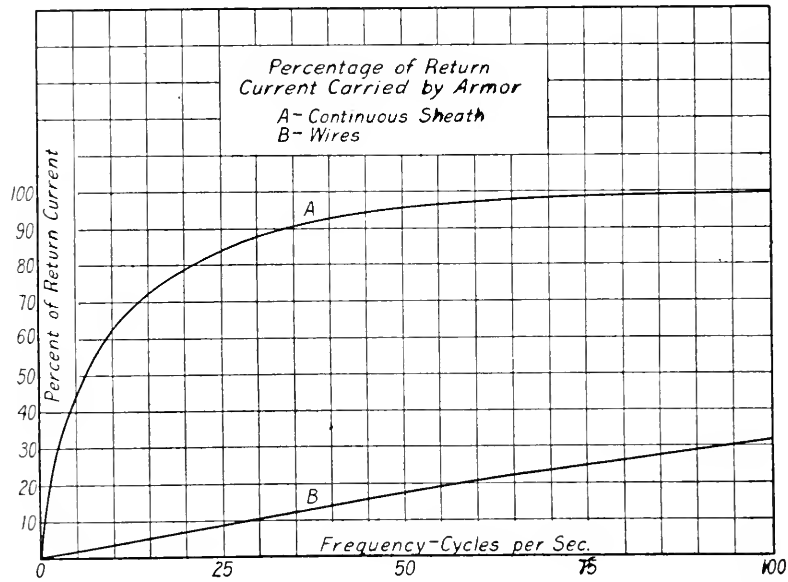
(4) Eliminate I_1 from these two relations, thus obtaining E_2 in terms of I_o. Then $Z_2 = -E_2/I_o$.

(5) Substitute this value of Z_2 and the value of Z_1 calculated from (55) in equation (58).

(6) The resistance and the inductance per unit length of the cable may then be determined from the real and imaginary parts of the latter equation.

The resistance and inductance of a cable of cross-section shown in Fig. 4 were computed by the method just described, the results being given by curves E and F of Fig. 3. The cable in this case is identical with that shown in Fig. 2 previously described,

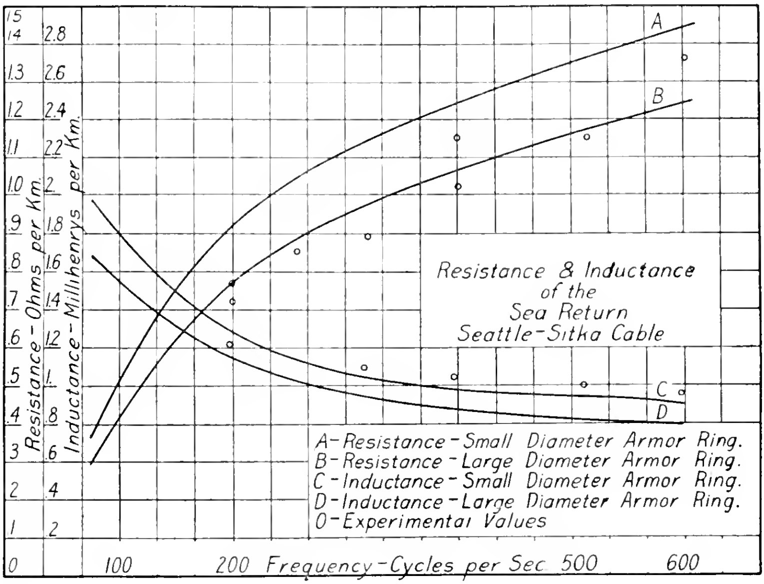
FIG. 6.



except that the continuous iron sheath has been replaced by fifteen wires. The effect of the presence of the iron upon the resistance of the return conductor is still noticeable, although it is much less than in the case of the continuous iron sheath. The reason for this is evident after inspection of the curves of Fig. 6, which show the percentage of return current carried by the armor in the two cases. Especially at the lower frequencies, the return current is much more confined by the continuous sheath than it is by the wires.

As a check of the method, the resistance and inductance of the Seattle-Sitka cable of the United States Signal Corps were calculater for frequencies in the range 50 to 600 cycles per second,

FIG. 7.



and the values so obtained were then compared with the results of measurements recently made upon this cable.[6] The constants used in the calculations were as follows:

Conductor	
Diameter	.216 cm.
Resistance per nautical mile	9 ohms
Rubber Insulation	
Outside diameter	.718 cm.
Capacity per nautical mile	.38 mf.
Armoring	
16 wires	each .242 cm. diameter
Outside Diameter of Cable	2.06 cm.

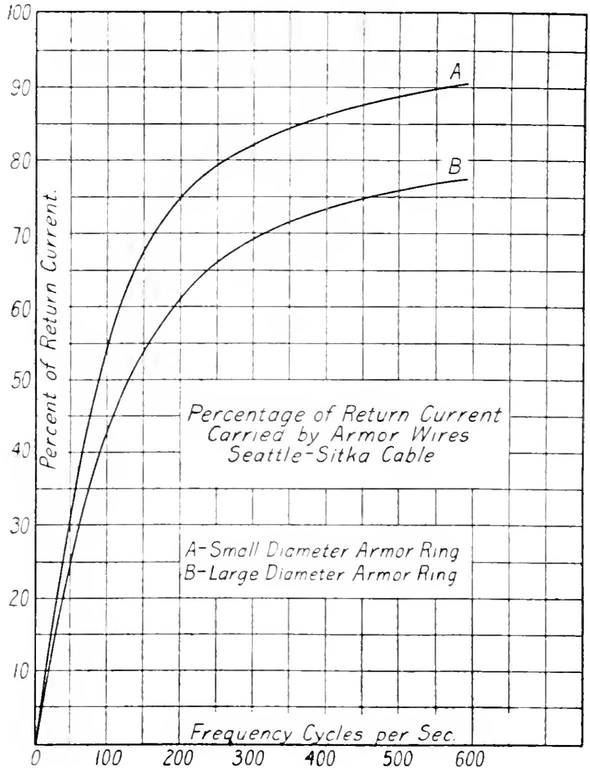
Owing to lack of information concerning the mean radius of the ring of armor wires, two sets of data were computed em-

[6] "The Use of Alternating Currents for Submarine Cable Transmission," Frederick E. Pernot, JOUR. OF THE FRANKLIN INSTITUTE, vol. 190, p. 323, 1920.

ploying the values $c=0.6148$ and $c=0.920$, which correspond, respectively, to zero and maximum separation of the armor wires.

The results of the calculations are shown in Fig. 7. The experimental values are indicated by small circles, and agree well with the theoretical values throughout the range of frequencies.

FIG. 8.



The resistance of the sea return increases most rapidly in the region of frequencies used in ordinary telegraphy, 0 to 100 cycles per second. In this range the inductance of the cable also has its greatest values, and these two effects have considerable influence in determining the transmission characteristics of the cable.

The percentage of the return current that is carried by the armor wires is shown in Fig. 8.

CONCLUSIONS.

As was previously pointed out, the effect of the shielding action of the iron armor of a submarine cable is to diminish the electromagnetic field which is propagated through the sea water, and which gives rise to the return current. Combined with this effect is the shielding action of the sea water adjacent to the cable, upon the distant portions. The total shielding effect increases with the frequency until a point is reached where practically the whole of the return current is carried by the armor wires.

Several remedies have been suggested for diminishing the damping effect of the armor wires. It can be proved, for example, that for a given size of core and weight of armor, the number and size of armor wires can be chosen so as to give a minimum value of return impedance. A proper choice of the electrical constants of the material of which the armor is constructed would also be of advantage, since the return impedance is somewhat larger for iron than it is for material of higher or lower conductivity.

Another method of diminishing the return impedance, which has been used in practice, is to wrap the cable core with a number of concentric layers of conducting tape before it is covered with jute. The return current, as it crowds in toward the core with increasing frequency, will then have a path of comparatively low impedance, and at the higher fequencies only a small portion of the current will be carried by the armor wires and the sea water. The impedance of the return path can be calculated for this case by the methods given in the preceding pages. The following table compares the values of the resistance of the return conductor calculated by three different methods, and determined experimentally, for a cable provided with a brass tape 5 mils in thickness.

Resistance of Return Conductor—OHMS per Statute Mile.

Frequency Cycles per Sec.	Approximate Method	Approx. Method* Corrected by Factor $\frac{2}{\pi}$	Exact Method	Experimental
3000	4.00	3.15	2.87	2.92
10000	4.90	4.25	4.45	4.60

*This is an empirical formula which has been found to be fairly close in most cases. The correction factor suggested itself in that it takes care of the increased surface of the armor wires, as compared with the corresponding continuous sheath.

The experimental values are the results of a series of measurements made by the Department of Development and Research of the American Telephone and Telegraph Company upon the Victoria-Vancouver submarine cable. The calculated values were obtained by both the approximate and the exact methods, discussed in the preceding pages, in which the armor of the cable is treated, respectively, as a continuous sheath and as a ring of wires. The modifications which must be introduced to include the effect of the conducting tape are outlined in the discussion of the general theory. The agreement between the calculated and the measured values of return resistance proves that the method developed in the present paper is accurate even at the highest frequencies employed in telephony.

NOTE I.

NOTE ON BESSEL FUNCTIONS.

The Bessel Functions of zero order of the first and second kinds, $J_0(\rho)$ and $K_0(\rho)$, used in the preceding work are all to a complex argument $\rho = iq\sqrt{i}$ where q is a real number and $i = \sqrt{-1}$. The following formulas may be used for determining the values of these functions:

$q < 0.1$

$$J_0(\rho) = 1 \qquad J_0'(\rho) = -\frac{1}{2}\rho$$

$$K_0(\rho) = \log_e \frac{2}{\gamma\rho} = .11593 - \log_e q - \frac{\pi i}{4}^*$$

$$K_0'(\rho) = -\frac{1}{\rho}$$

(*Jahnke u. Emde*, "Funktionentafeln," pp. 97, 98.)

$0.1 < q < 10$

The report of the British Association for 1912 and 1915 give the values in this range of the functions ber q, ber$'q$, bei q, bei$'q$, ker q, ker$'q$, kei q, kei$'q$ which are defined by the relations

*It is to be noted that this approximation for $K_0(\rho)$ differs from the expression used by J. J. Thomson, "Recent Researches in Electricity and Magnetism," p. 263. Thomson's formula (2), from which his approximation was derived, contains a number of errors and should read

$$K_0(x) = (-C + \log 2i - \log x)J_0(x) - 2J_2(x) - \frac{1}{2}J_4(x) + \frac{1}{3}J_6(x) \ldots\ldots,$$

where $C = .5772 = \log \gamma$.

$$J_0(iq\sqrt{i}) = \mathrm{ber}\, q + i\, \mathrm{bei}\, q\ ,$$

$$i\sqrt{i}\ J_0'(iq\sqrt{i}) = \mathrm{ber}' q + i\, \mathrm{bei}' q\ ,$$

$$K_0(iq\sqrt{i}) = \mathrm{ker}\, q + i\, \mathrm{kei}\, q\ ,$$

$$i\sqrt{i}\ K_0'(iq\sqrt{i}) = \mathrm{ker}' q + i\, \mathrm{kei}' q\ .$$

$q > 10$

$$J_0(q\sqrt{-i}) = \frac{\varepsilon^{q/\sqrt{2}}}{\sqrt{2\pi q}}\left[\cos\left(\frac{q}{\sqrt{2}} - \frac{\pi}{8}\right) - i\sin\left(\frac{q}{\sqrt{2}} - \frac{\pi}{8}\right)\right],$$

$$J_0'(q\sqrt{-i}) = -i\, J_0(q\sqrt{-i}),$$

$$K_0(q\sqrt{-i}) = \frac{\varepsilon^{-q/\sqrt{2}}}{\sqrt{\frac{1}{2}\pi q}}\left[\sin\left(\frac{q}{\sqrt{2}} + \frac{\pi}{8}\right) + i\cos\left(\frac{q}{\sqrt{2}} + \frac{\pi}{8}\right)\right],$$

$$K_0'(q\sqrt{-i}) = i\, K_0(q\sqrt{-i}).$$

(*Jahnke u. Emde*, pp. 101, 102.)

NOTE II.

TRANSFORMATION OF FOURIER-BESSEL EXPANSION.

In problems involving Fourier-Bessel expansions it is sometimes necessary to transform quantities of the form

$$\frac{\cos s\phi_j}{\rho_j^s},\ \frac{\sin s\phi_j}{\rho_j^s},\ \log \rho_j\ ,$$

from the system of coördinates ρ_j, ϕ_j to the systems ρ, ϕ or r, θ which are related as shown in Fig. 5.

The necessary formula may be derived as follows. We have

$$\frac{\cos s\phi_j + i\sin s\phi_j}{\rho_j} = \frac{\varepsilon^{is\phi_j}}{\rho_j^s} = \left(\frac{\varepsilon^{i\phi}}{\rho_j}\right)^s = \frac{1}{Z_j^s},$$

where Z_j is the conjugate of the vector $Z'_j = \rho_j \varepsilon^{i\phi_j}$. Similarly we may write

$$Z = \rho\varepsilon^{i(\phi - \pi + 2a_j)},$$

$$C_j = c_j\varepsilon^{i(\pi + a_j)}$$

The vectors Z_j, Z and C, as may be seen from Fig. 5, have the lengths ρ_j, ρ and c, respectively, and the directions indicated by the arrows.

By vector addition,

$$Z'_j = Z + C_j$$

whence

$$Z_j = Z' + C'_j,$$

where Z' and C'_j are the conjugates of Z and C_j respectively.

By expansion

$$\frac{1}{Z_j^s} = \frac{1}{(Z' + C'_j)^s} = \frac{1}{C_j'^s}\left[1 - \frac{s}{1}\,\frac{Z'}{C'_j} + \frac{s(s+1)}{1.2}\,\frac{Z'^2}{C_j'^2} - \frac{s(s+1)(s+2)}{1.2.3}\,\frac{Z'^3}{C_j'^3} + - - \right].$$

We have

$$\frac{1}{C_j'^s} = \frac{\varepsilon^{is(\pi + a_j)}}{C_j^s} = (-1)^s \frac{\varepsilon^{isa_j}}{C_j^s},$$

and

$$\frac{Z'^n}{C_j'^n} = \frac{\rho^n}{C_j^n}\varepsilon^{in(2\pi - \phi - a_j)} = \frac{\rho^n}{C_j^n}\varepsilon^{-in(\phi + a_j)}$$

Therefore

$$\frac{\varepsilon^{si\phi_j}}{\rho_j^s} = \frac{1}{Z_j^s} = \frac{(-1)^s}{C_j^s}\left[\varepsilon^{isa_j} - \frac{s}{1}\,\frac{\rho}{C_j}\varepsilon^{-i(\phi - a_j(s-1))} + \frac{s(s+1)}{1.2}\,\frac{\rho^2}{C_j^2}\varepsilon^{-i(2\phi - a_j(s-2))} - \right]$$

Equating the real and imaginary parts gives

$$\frac{\cos s\phi_j}{\rho_j^s} = \frac{(-1)^s}{C_j^s}\left[\cos sa_j - \frac{s}{1}\,\frac{\rho}{C_j}\cos(\phi - a_j[s-1]) + \frac{s(s+1)}{1.2}\,\frac{\rho^2}{C_j^2}\cos(2\phi - a_j[s-2]) - - - - - \right]$$

$$\frac{\sin s\phi_j}{\rho_j^s} = \frac{(-1)^s}{C_j^s}\left[\sin sa_j + \frac{s}{1}\,\frac{\rho}{C_j}\sin(\phi - a_j[s-1]) + \frac{s(s+1)}{1.2}\,\frac{\rho^2}{C_j^2}\sin(2\phi - a_j[s-2]) - - - - - - \right].$$

Similarly

$$\log Z_j = \log (C'_j + Z')$$

$$= \log C_j + \frac{Z'}{C'} - \frac{1}{2}\frac{Z'^2}{C'^2} + \frac{1}{3}\frac{Z'^3}{C'^3} - - - - - - - -$$

$$= \log C_j + \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n} \frac{\rho^n}{C_j^n} \varepsilon^{in(\phi - a_j)}.$$

Equating real and imaginary parts we have

$$\log \rho_j = \log C_j + \frac{\rho}{C_j}\cos(\phi - a_j) - \frac{1}{2}\frac{\rho^2}{C_j^2}\cos 2(\phi - a_j) + \cdots + ,$$

$$\phi_j = \frac{\rho}{C_j}\sin(\phi - a_j) - \frac{1}{2}\frac{\rho^2}{C_j^2}\sin 2(\phi - a_j) + \cdots + .$$

The following formulas may be derived in a similar manner:

$$\frac{\cos s\phi_j}{\rho_j^s} = \frac{(-1)^s}{C^s}\left[1 + \frac{s}{1}\frac{r}{c}\cos(\theta - \gamma_j) + \frac{s(s+1)}{1.2}\frac{r^2}{c^2}\cos 2(\theta - \gamma_j) + \cdots + \right],$$

$$\frac{\sin s\phi_j}{\rho_j^s} = \frac{(-1)^{s+1}}{C^s}\left[\frac{s}{1}\frac{r}{c}\sin(\theta - \gamma_j) + \frac{s(s+1)}{1.2}\frac{r^2}{c^2}\sin 2(\theta - \gamma_j) + \cdots + \right],$$

$$\log \rho_j = \log c - \frac{r}{c}\cos(\theta - \gamma_j) - \frac{1}{2}\frac{r^2}{c^2}\cos 2(\theta - \gamma_j) - - - - - .$$

NOTE III.

DETERMINATION OF q_1, q_2, ETC.

The equations (47),

$$q_n = (-1)^n \lambda_n \frac{\zeta^{2n}}{n}(A + S_{nn}B_0) - (-1)^n \lambda_n \frac{\zeta^{2n}}{n!}\Sigma_n, \quad n = 1 - - \infty$$

are linear in the variables q_1, q_2 –, since

$$\Sigma_n = n!\, S_{n-1,n+1} q_1 - \frac{n!}{1!} S_{n-2,n+2} q_2 - - - .$$

The values q_1, q_2 ... may be determined by a method of approximations, q_n being the limit of the sequence

$$q_n^{(0)}, \ q_n^{(1)}, \ q_n^{(2)} - - - - - ,$$

the successive terms of which are defined by the expressions

$$q_n^{(0)} = (-1)^n \lambda_n \frac{\zeta^{2n}}{n} (A + S_{nn} B_0) ,$$

$$- - - - - - - -$$

$$q_n^{(j+1)} = (-1)^n \frac{\zeta^{2n}}{n!} (A + S_{nn} B_0) - (-1)^n \frac{\zeta^{2n}}{n!} \Sigma_n (q^{(j)}) ,$$

where $\Sigma_n(q^{(j)})$ is the value of Σ_n when $q_1, q_2 -$ are replaced by $q_1^{(j)}, q_2^{(j)} - - -$.

This method, however, while formally simple and direct is not usually well adapted for numerical solution. For all sizes of armor wire and for frequencies of practical importance the argument ζ in the expression (48) is small compared with μ and the quantities,

$$\lambda_1 , \lambda_2 - - -$$

are all nearly unity. This suggests the use of the following method of solution of equations (47).

The solution of the auxiliary set of equations

$$p_1 = -\zeta^2 (A + S_{11} B_0) + \frac{\zeta^2}{1!} \Sigma_1(p) ,$$

$$- - - - - - - -$$

$$p_n = (-1)^n \frac{\zeta^{2n}}{n} (A + S_{11} B_0) - (-1)^n \frac{\zeta^{2n}}{n!} \Sigma_n(p)$$

in the auxiliary variables $p_1, p_2 -$ may be written,

$$p_1 = -\zeta^2 C_{11} (A + S_{11} B_0) + \frac{\zeta^4}{2} C_{12} (A + S_{22} B_0) + \cdots + ,$$

$$- - - - - - - - - - - -$$

$$p_n = -\zeta^2 C_{n1} (A + S_{11} B_0) + \frac{\zeta^4}{2} C_{n2} (A + S_{22} B_0) + \cdots + ,$$

in which C_{11}, etc., are numerics. This solution is effected by retaining a finite number of equations and an equal number of variables and solving by the usual methods. It will be found that

except in extreme cases, a very good approximation can be gotten by ignoring all the p's except the first four. The q's may then be obtained by the relation

$$q_n = p_n + d_n$$

d_n being defined by

$$d_n = (\lambda_n - 1)p_n - (-1)^n \lambda_n \frac{\zeta^{2n}}{n!} \Sigma_n(d).$$

This system is easily adapted to solution by successive approximations,

$$d_n = d_n^{(o)} + d_n^{(1)} + d_n^{(2)} + - - -$$

in which

$$d_n^{(o)} = (1 - \frac{1}{\lambda_1}) C_{n1} p_1 + \cdots + (1 - \frac{1}{\gamma_n}) C_{nn} p_n \ ,$$

$$d_n^{(j+1)} = (1 - \frac{1}{\lambda_1}) C_{n1} d_1^{(j)} + \cdots + (1 - \frac{1}{\lambda_n}) C_{nn} d_n^{(j)} \ ,$$

C_{n1}, etc., being the numerical coefficients which appear in the expressions for p_1, p_2–.

A very good approximation which holds in most cases is

$$d_n = (\lambda_1 - 1) C_{n1} p_1 + (\lambda_2 - 1) C_{n2} p_2 + \cdots + (\lambda_n - 1) C_{nn} p_n \ .$$

FEBRUARY 15, 1921.

Compressibility of Aromatic Hydrocarbons. THEODORE W. RICHARDS, EDWARD P. BARTLETT, and JAMES H. HODGES, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1539–1542), find that *solid* benzene at a temperature of 0° C. has a compressibility of 0.0000305 over the range of 100 to 500 megabars, and that *liquid* benzene at a temperature of 20° C. has a compressibility of 0.00007207 over the same range. *Liquid* toluene at a temperature of 0° C. has a compressibility of 0.0000618 over the range stated.

J. S. H.

Studies of Nitroprussic Acid. GEORGE JOSEPH BURROWS and EUSTACE EBENEZER TURNER, of the University of Sydney (*Jour. Chem. Soc.*, 1921, cxix, 1450–1452), have prepared nitroprussic acid and certain of its derivatives. The free acid is obtained as reddish-brown leaflets when an aqueous solution of its barium salt is treated with the calculated amount of sulphuric acid, the precipitated barium sulphate is removed by filtration, and the filtrate is evaporated under diminished pressure. The acid has the formula $H_2Fe(CN)_5NO$; it is readily soluble in water, but the solution is unstable. Its 0.05 normal aqueous solution is approximately 85 per cent. dissociated, as is shown by the conductivity. The acid combines directly with organic bases like pyridine and benzidine to form the corresponding salts. The tetramethylammonium salt has also been prepared. Diethyl nitroprusside is formed by the reaction between silver nitroprusside and an alcoholic solution of ethyl iodide. The ester occurs as red prismatic crystals. Determination of the freezing point of its aqueous solution showed that the ester was dissociated, one molecule of the ester yielding one molecule of nitroprussic acid and two molecules of ethyl alcohol.

J. S. H.

The Transformation of Iron at the Curie Point. P. DEJEAN. (*Comptes Rendus*, August 22, 1921.)—By a ballistic method the intensity of magnetization of a stack of carefully turned cylinders of soft steel was investigated as the interstices between adjacent pieces was progressively increased. From the results curves were plotted giving, for each field strength used, the connection between the intensity realized and the interval between neighboring cylinders. This family of curves resembles that obtained in 1895 by Pierre Curie to express the connection of temperature with intensity for varying strengths of field. Interval in one case plays the same rôle as temperature in the other. This analogy leads to the suggestion that it is the progressive separation of the molecular magnets due to elevation of temperature that accounts for the apparent effect of temperature on magnetic intensity. Such progressive separation may be brought about by the gradual transformation of a magnetic form of iron into a non-magnetic form or by an actual, linear separation brought about by the application of heat.

The Curie Point, that is, the temperature at which a magnetic substance ceases to show magnetic properties, rises when the strength of the applied field is made greater. The author ingeniously adduces this fact in favor of his hypothesis that it is in an increase of distances between the magnetic particles that the explanation is to be sought. Were such a particle to lose its magnetic qualities at some temperature, why should it retain them to a higher temperature merely because a stronger field is acting?

G. F. S.

THE SHAPE ASSUMED BY A DEFORMABLE BODY IMMERSED IN A MOVING FLUID.*

BY

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I. INTRODUCTION.

THE purpose of this article is to discuss from what appears to me to be an entirely new viewpoint, the question of the relation between the shape of an immersed body and the forces acting upon it due to the motion of the fluid. Considerable attention has been given to certain important aspects of this subject. For instance, much work has been done in the determination of the magnitude of the resistance experienced by variously shaped bodies when moving through a fluid at various speeds. This matter is of grave importance in aeronautics.[1] Likewise the distribution of pressure due to motion over bodies of certain shapes has been studied more or less extensively.[2] We may now, however, ask the more general question: What shape will a deformable body assume when immersed in a moving fluid? The behavior of such a body moving in a fluid seems never to have been considered in this regard.

This question was first forcibly pressed into my attention during the exhaustion of the bulb of a mercury arc lamp, when some observations were incidently made on the behavior of a mercury drop. These observations are the only experimental evidence that I am able to put forward at present to substantiate the theme of this paper, that a perfectly deformable body immersed in a moving fluid will assume a shape whose defining contour lines are "stream-lines." No body is, however, perfectly deformable so that in all practical cases, the body will change toward the stream-line shape

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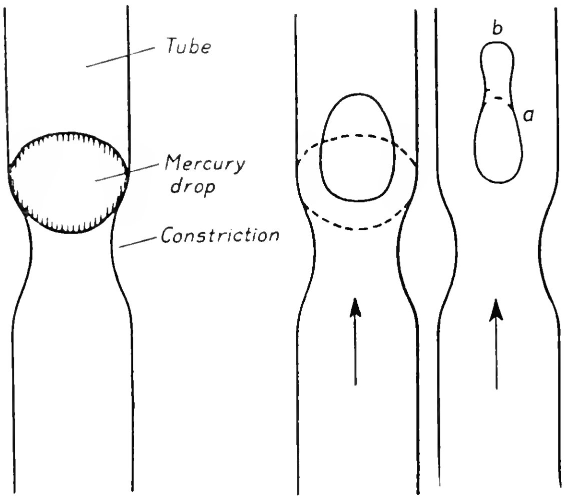
* Communicated by M. Luckiesh, Director of the Laboratory.

[1] Reference may be made to the Reports of the National Research Council, Aeronautics Section, for some recent work in this regard.

[2] See Bureau of Standards Scientific Paper No. 394, or *Bul. B. of S.*, p. 489, 1920, for recent data and reference to former results.

until there is equilibrium between the forces of restraint in the body and the forces due to the pressure of the moving fluid. In case of the mercury drop there must be, when the steady state is attained, equilibrium between the forces of surface tension and of pressure. The effect of gravity also can not be ignored in all cases.

FIG. 1. FIG. 2. FIG. 3.



The shape of a mercury drop.

A little reflection will bring forth many possible illustrations of the phenomenon in widely separated realms of science—physics, geology, meteorology, and biology.[3]

II. OBSERVATIONS ON A MERCURY DROP.

When a drop of mercury is retained in a tube and a current of air is drawn over it, the shape of it will change. The conditions under which this was first observed are depicted in Fig. 1. A

[3] While searching the literature for suggested illustrations I had the pleasure of very soon encountering the works of Vaughan Cornish, through the kindness of Mr. C. K. Wentworth. (The latter has been interested in the experimental study of the shapes of pebbles. *J. of Exp. Geol.*, 27, p. 507, 1919.) Cornish pointed out after extensive and painstaking observations, that many shapes due to wind and other factors are of definite and uniform type. One cannot help but see some intimation, rather indefinitely expressed in his descriptions and explanations, of the general principle which I am endeavoring to show lies at the bottom of all such forms.

vertical glass tube of about 8 mm. diameter was constricted just sufficiently to retain a rather large drop of mercury. The upper end of the tube was connected to a vacuum pump; the lower end to a mercury lamp. During the exhaustion the mercury lamp was vigorously heated, and as a consequence some of the mercury evaporated and condensed upon the walls of the tube near the constriction, collecting there to form a good-sized drop. Subsequently a small crack developed in the lamp, allowing the air to rush into the evacuated chamber. The stream of air changed the shape of the drop in a most interesting manner. When the air current was not too great the shape of the mercury drop was like that shown in Fig. 2,[4] where the dotted line indicates the shape and position of the drop in repose, and the full line represents the assumed form while the air was rushing by. The drop is elongated in the direction of the air current with the convexity of the blunter end directed against the stream.

When the air stream is allowed to become too great the mercury drop breaks and breaks in a manner that might not be expected, at all events not in a manner that one might be lead to believe from the statements sometimes made as to the breaking of drops. As the velocity of the air becomes greater the globule lengthens, but the lengthening is not entirely at the sacrifice of the general cross-section; rather, the cross-section of the portion of the globule at *a,* Fig. 3, is particularly decreased until the rear portion breaks away. It is impossible to see with the unaided eye the changes taking place in the new-born drop on account of its motion with the stream of gas. It undoubtedly readjusts its shape to conform to the prevailing conditions of streaming. During the formation of it there is also much agitation, and the elongated portion of the drop oscillates violently—suggestive of the existence of unstable conditions there.

This behavior suggests very vividly that the mercury drop adjusts its shape to the conditions of streaming, and as these conditions are dependent largely upon the relative velocity of streaming the mercury drop assumes a different shape for every velocity. It will assume a shape such that the defining contour lines approach steam-lines.

[4] Figs. 1–3 were drawn from memory a few days after the experiments, when the general possible significance of the incidence became convincive.

Is this not indicative of what all deformable or corrodible bodies will do? It is to be expected from the facts that are known regarding the resistance encountered by a body when moving through a fluid. Bodies whose contour lines are stream-lines experience the least retardation. One might expect therefore the inverse phenomenon to take place; namely, that in a body moving through a fluid, there will be set up forces whose directions and magnitudes are such as to cause the body to assume as closely as possible, the shape offering least resistance.

For the sake of brevity this phenomenon will occasionally be referred to as the Principle of *Stream-line Assumption.*

As has already been stated, experimental data are not at hand to be mustered together in order to weigh the generality of the principle. The experiments with the mercury drop gave confirmatory evidence again and again. Whether or not the conditions were too special to allow of any generalization at all can only be decided by further experiments. I will now, however, consider the support which may be found in other realms of science for the generality of the principle of stream-line assumption.

III. OTHER LINES OF EVIDENCE.

a. SHAPES OF SNOWDRIFTS.

Some of the obvious [5] phenomena in which one might expect to obtain evidence of the play of such a principle are in the formation of sand dunes and snowdrifts. In snowdrifts a general characteristic profile has been pointed out by Cornish,[6] who has made numerous and painstaking observations on phenomena of this kind. This profile is depicted by the curve of Fig. 4,[7] the blunt end of which is to windward. This is a most beautiful confirmation of our text. Cornish has named this profile curve the "Eddy-curve." Although this term is connotative of the process of formation of these forms, in that during the formation the curve may be an envelope of numerous eddy currents, yet I prefer

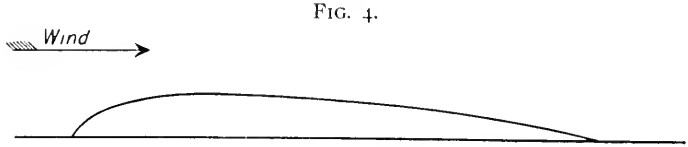
[5] At least most obvious to one who has vivid and delightful recollections of snowdrifts seen during boyhood in and near the Olympic Mountains.

[6] "Waves of Sand and Snow." From these works I am drawing freely for illustrations, and with much appreciation.

[7] This figure and several that follow are taken from Cornish, "Waves of Sand and Snow."

to use the phrase "stream-line" curve or contour. For the latter term refers more definitely to the thing that we are interested in rather than to the process of formation of it. Futhermore, it is the concept of the stream-line contour and its relations to the resistance offered by bodies to moving fluids that has been a guide in arriving at an explanation of shapes of snowdrifts and the like, and in the prediction of the existence of such shapes in

FIG. 4.

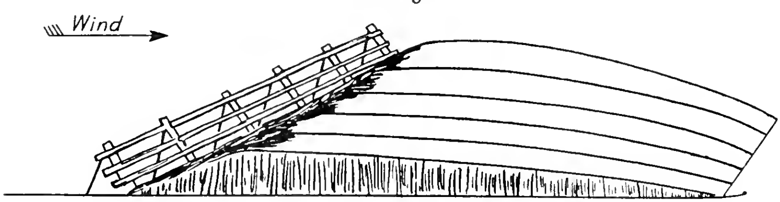


The fundamental curve of snowdrifts. (Redrawn from Cornish.)

certain other cases that had not previously come into my experience.

We may take again from Cornish some excellent examples of the shapes of snowdrifts. In Fig. 5 is shown a snowdrift formed by the obstruction of a fence. In Fig. 6 is a similar one where the fence has become incidental and is no longer the limiting boundary on the windward side. The outline and the cross-section of a snowdrift caused by a clump of bushes are shown

FIG. 5.

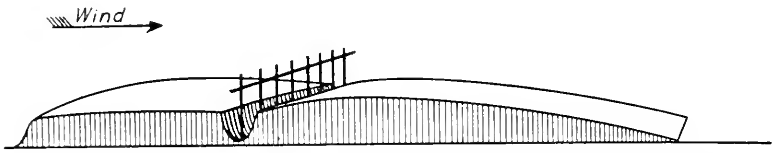


Fence and completed snowdrift. (Redrawn from Cornish.)

in Figs. 7, 8, and 9. A similar case where a house is the incipient interference is shown in Figs. 10, 11, and 12. Another interesting illustration of this type is shown in Figs. 13, 14, and 15, where a round, upright tree causes a hollow to be formed in the drifted snow. This case is interesting because it may be thought of in connection with the experimental work discussed later bearing upon the distribution of pressure over the surface of a round cylinder immersed in moving air. These are illustrations of the formation of barriers rather than of a mere reshaping of bodies. Yet the restraining forces are there, evidenced by the moulding

of these obstacles to the stream-line contour. This shaping lends some assurance that had the drifts been cubical or irregular masses initially, they would, nevertheless, have been shaped to this very same contour.

FIG. 6.

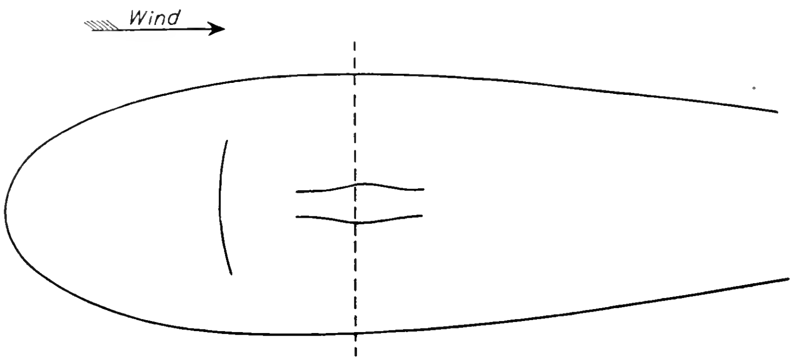


Snowdrift on both sides of a fence; on the right completed, on the left incomplete. (Redrawn from Cornish.)

b. GEOLOGICAL FORMS.

Some examples of the actual shaping of already existing bodies might be looked for in the geological forms. Here, however, there are so many factors of corrosion affecting shape, that it is difficult to select illustrations which show clearly the working of

FIG. 7.



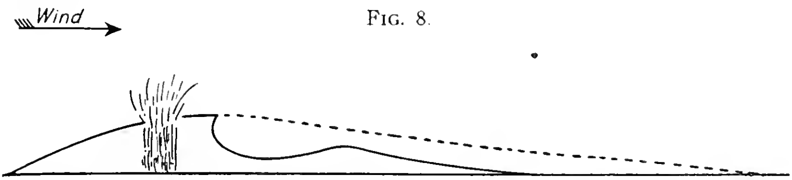
Plan of snowdrift caused by clump of bushes. (Redrawn from Cornish.)

this principle. The forms of erosion, where air or water currents are by virtue of their motion the chief agents of erosion, would present data for decisive judgment. In all actual cases other factors concerned such as the original jointing and lay of the strata, and temperature changes and moisture, may overwhelmingly affect the shape of boulders and the like. The illustrations in Fig. 16 are given without any idea of selection, but are given because they were immediately available.

The so-called "windtables" and erosion pillars may be noted in this connection. Some excellent specimens of the first may be seen in the Petrified Forests of Arizona. The boulders in Fig. 16[8] are at first sight strikingly suggestive of our theme.

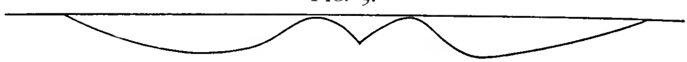
The boulders are of granite that is "a coarse-grained, pale red granite composed of quartz, orthoclase, plagiocase and bio-

FIG. 8.



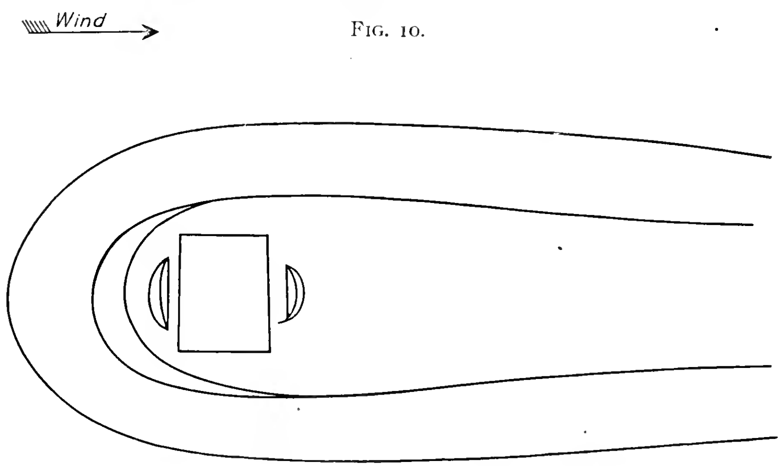
Profile (dotted) and central longitudinal section of the same drift. (Redrawn from Cornish.)

FIG. 9.



Section across dotted line of Fig. 8. (Redrawn from Cornish.)

FIG. 10.



Plan of the principal snowdrift around a house on the prairie near Winnipeg. (Redrawn from Cornish.)

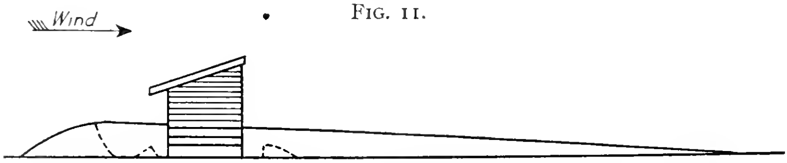
tite in decreasing order of abundance. The average grain size is from 3 to 4 mm., the orthoclase ranging up to 5 mm. long. The height above sea-level at which these boulders occur is 4070 feet

[8] This illustration is taken from Gregory, Australia, *The National Geographical Magazine*, p. 474, December, 1916. For the description (in quotation marks) of them I am indebted to Dr. H. C. Richards, Professor of Geology, University of Brisbane, Brisbane, Australia.

and as they are on the top of a rather bare mountain, they are exposed to rather severe weather conditions. The long axes of these boulders run almost due east and west."

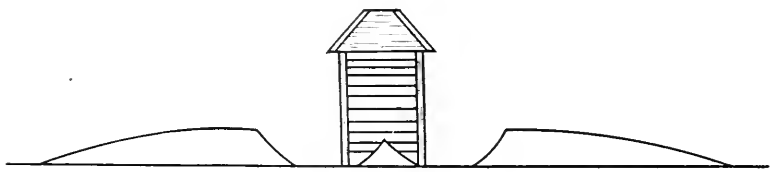
The prevailing winds to which they are exposed are southeasterly in summer and autumn; and westerly in winter and spring. So that during the winter and spring winds blow along the major axis of the boulders, while during summer and autumn the prevailing winds blow obliquely to the major axis. Of course this is a very approximate statement because the winds coming from various directions at the various seasons should be weighted in accordance to their effectiveness as corrosive agents. It might be expected that the winter and spring winds would be more effective than the summer winds. Greater details as to the direction of the winds for this case are given in the following table: [9]

FIG. 11.



Profile and central longitudinal section of same snowdrift. (Redrawn from Cornish.)

FIG. 12.



Transverse section of snowdrift on lee side of an outhouse on the prairie. (Redrawn from Cornish.)

Wind Directions at Stanthorpe (1907–1920).

Season	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm
	%	%	%	%	%	%	%	%	%
Spring	3	2	11	16	2	8	27	5	26
Summer	3	7	18	25	3	9	14	3	18
Autumn	3	4	16	24	3	6	15	2	27
Winter	2	2	8	12	2	9	22	2	41

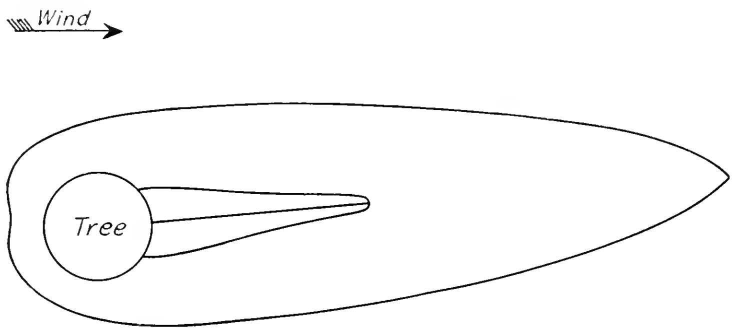
The most striking feature of these winds is that a large per-

[9] Data furnished by Professor Richards, taken from the *Commonwealth Meteorologist.*

centage of them during all seasons have a component east and west; while the total component north and south is relatively small.

Examples of boulders such as in Fig. 16 may be multiplied,[10]

FIG. 13.

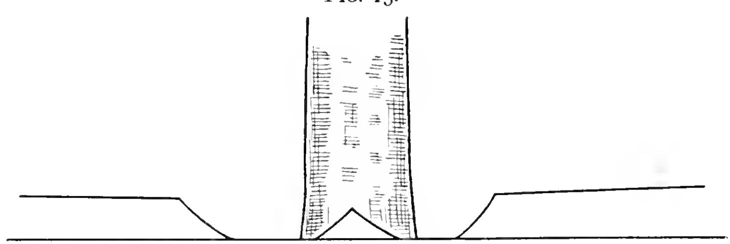


Plan of a hollow around a tree. (Redrawn from Cornish.)

FIG. 14.

Longitudinal section of same. (Redrawn from Cornish.)

FIG. 15.



Cross-section of the same—lee side. (Redrawn from Cornish.)

but for the present not to advantage, for until sufficient data are available they are only suggestive and not illustrative of our theme.

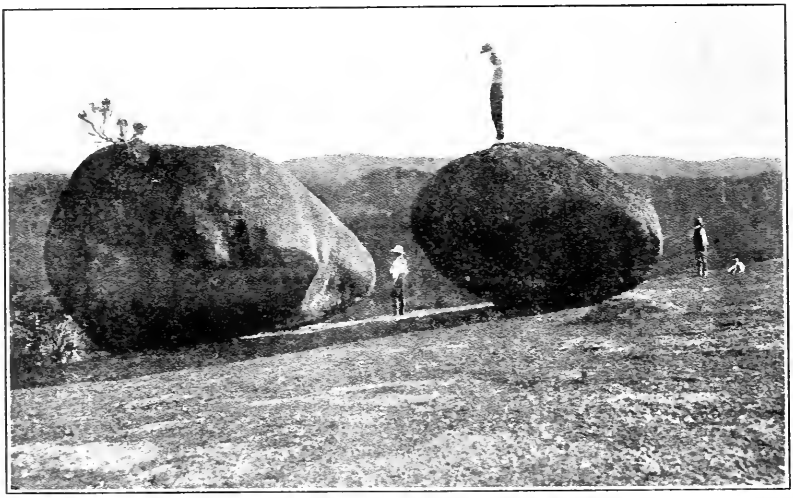
[10] For example, "The Leviathan" and "The Torpedo" and many others in the Buffalo mountains, Victoria, Australia (see *Memoirs of the Geological Survey of Victoria,* 1918, No. 6. The Buffalo Mountains, plates 37 and 40). These were brought to my attention by Professor Richards. They may yield evidence of this phenomenon upon closer analysis of the conditions.

c. OTHER METEOROLOGICAL FORMS.

Very similar to some of these geological forms are the meteorological forms termed "bosses of snow" and "snow mushrooms" pictured in Figs. 17, 18, and 19.[11]

Other meteorological illustrations might be looked for in moving clouds and in fact wherever a portion of the air is made stagnant from some cause or other, such as the "pockets" reported by aeronauts. In observing the clouds for this phenome-

FIG. 16.



Shape of boulders. (Taken from *National Geographic Magazine*, Dec., 1916, page 474.)

non I have seen some excellent specimens of small cumulus clouds, which had a general stream-line appearance and moved with the blunt end forward. In general, however, there appear to be so many factors tending to change the shapes of clouds so rapidly that the number of favorable cases is small. At least this is true in the horizontal section. It is probable that the vertical section would also present the stream-line contour at times, but this viewpoint is seldom to be had.

The so-called "pockets" in the air mentioned above might be expected to have a stream-line contour. No data concerning them are available. Very closely related to such pockets are the relatively

[11] Taken from Cornish, "Waves of Sand and Snow."

stagnant portions produced by some obstacle such as a tree, as is illustrated in Fig. 13. This matter will be referred to again when convectional streaming is discussed.

FIG. 17.

"Bosses" of snow. (Taken from Cornish.)

Still further illustrations may be seen in the so-called snow barchans typified in Fig. 20 and in Fig. 21.[12] These forms may quite frequently be seen on hard roads during cold weather when a light, dry snow is drifting. The raindrop is generally regarded as spherical. It probably is not, for we would expect to find some

[12] Taken from Cornish.

reshaping of it in accord with the principle of stream-line assumption, both for the velocity of falling and for any other relative velocity due to the wind. I had hoped, but now find it impossible,

FIG. 18.

Snow "mushroom." (Taken from Cornish.)

to present data bearing upon this point as well as upon the shape of a falling mercury drop, and upon the manner of breaking up of drops during falling. Icicles too frequently have cross-sectional contours bearing evidence of our theme. Reference will again be made to them when the distribution of forces is considered.

d. BIOLOGICAL FORMS.

Turning now from the realms of geology and of meteorology to the realm of biology, we find illustrations of the working of the principle of stream-line assumption upon the living organism.

FIG. 19.

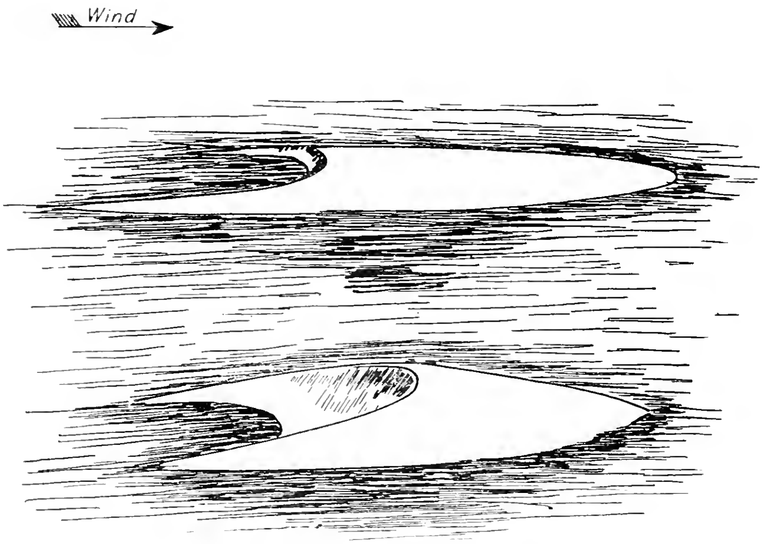
Snow "mushroom." (Taken from Cornish.)

It has always been a matter of much comment that the shapes of many fishes conform very closely to the stream-line contour. According to the view put forth herein any moving body of any shape immersed into a fluid is subjected to forces of restraint that are least when the body has a shape whose contour lines are

stream-lines. Any deformable body will assume that shape. The living organism then has assumed the shape that any deformable inanimate body would. Other familiar examples are found in the case of birds, where not only the shape of the body, but the thickening of the front portion of the wing and the lay of the feathers are conspicuous from this standpoint.

It is perhaps somewhat trivial to point out that the general shapes of many trees and plants is such that as they bend to the wind they present an approximate stream-line contour. It would

FIG. 20.



Barchans of snow and sand. (Redrawn from Cornish.)

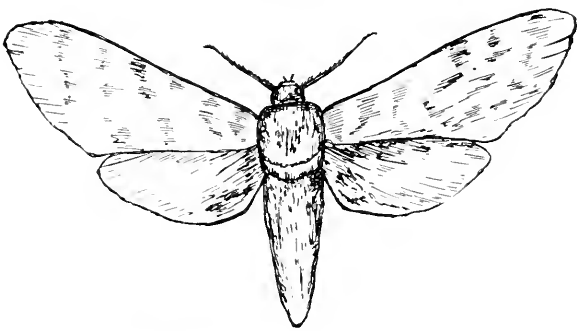
seem that shapes of seeds and fruit that are dispersed by winds, or by forceful ejections, should present illustrations. I have found none but the proper data are very frequently not on record to enable a decision to be made.[13] Still other illustrations in the realm of biology we should expect to find among the insects, as the butterflies. The features which we are seeking should be enhanced among those species which are quick of flight, strong of wing, and which have relatively heavy bodies. In the so-called hawkmoths (*Spingideæ*) we do find most striking verification

[13] I have Dr. Annie May Hurd to thank for assistance in references in this connection.

FIG. 21.

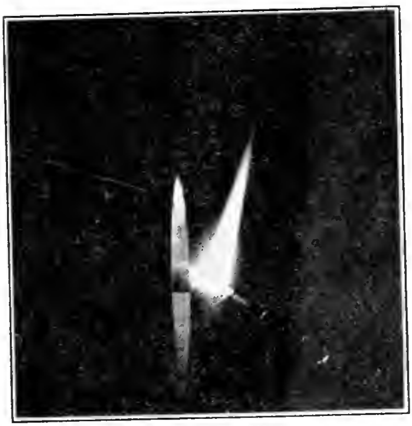
Erosion form analogous to a barchan. (Redrawn from Cornish.)

FIG. 22.



Hawkmoth (*Spingideæ*) having a relatively heavy body of stream-line contour and small but powerful wings.

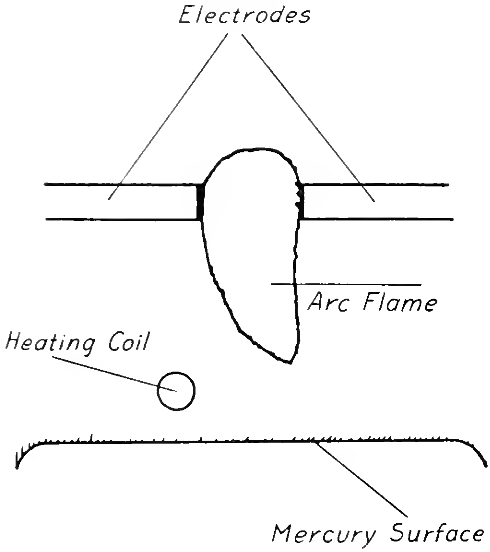
FIG. 23.



Shape of the flame of the high intensity searchlight arc.

of our principle. I have observed this species rather closely in this regard. The hawkmoth has rather elongated wings, with thickened front edges; the area of the wing surface compared with the weight of the body being appreciably smaller than is found in the case of most lepidoptera. It is, however, one of the most powerful on the wing of them all.[14] The form of its body

FIG. 24.



Shape of the tungsten arc flame.

is certainly most strikingly adapted, as shown in Fig. 22.

The assumption of the stream-line shape by organisms where proper conditions exist may be looked upon in the same light as the adjustment of organisms under a field of force as that of gravity (geotropism), or the orientation, as of leaves, under conditions of directed illumination (heliotropism, phototropism). The forces are constantly present. It would be interesting and be of good evidence to find in case of birds and fish, that there is an adjustment for different conditions of living. For example, the stream-line contour should be different or different speeds of flight and of different relative speeds of current and fish.

[14] I have seen specimens of it that, while imprisoned in a hat covered with a plate of glass, sustained themselves almost motionless at the centre of the hat for an appreciable length of time.

The phenomenon appears to be of sufficient importance to be specifically designated as the other similar phenomena of heliotropism, geotropism, galvanotropism. For this designation I venture to suggest the term, *rheotropism* (stream adjustment).

e. ILLUSTRATIONS FROM PHYSICS.

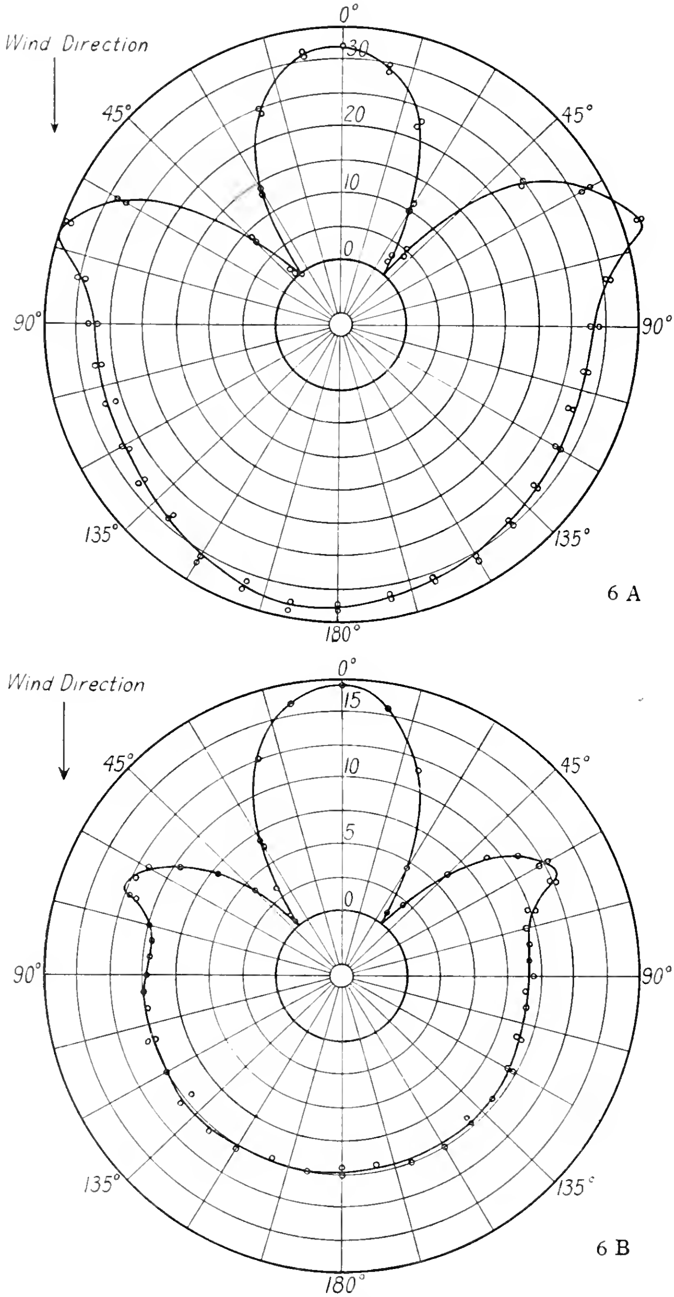
The shape of stagnant spots in streaming air has already been referred to. Other instances very closely related to this are the shape of a candle flame, and the shape of the flame or arc in the

FIG. 25.

Shape of the dark space formed around a heated wire.

high intensity searchlamps so extensively used for military purposes during the late war. A picture of the latter is shown in Fig. 23. The shape of the flame in the mercury tungsten arc, Fig. 24, is likewise interesting in this connection. The streaming in these cases consists merely in the convection currents, which in the instances just cited are rather violent. In Fig. 25, where the dark space that forms around heated wire in dusty air is shown, convection is less violent. Yet even here the shape of the boundary of the dark space in the neighborhood of the wire may be noted. The temperature of the wire in the present case was that of dull-redness. The streaming is made visible by the introduction of ammonia hydrochloride. The horizontal dark space is the shadow of the wire.

FIG. 26.



Distribution of pressures around cylinders in streaming air. (Taken from *Bul. B. S.*, 16, p. 489, 1920.)

f. EVIDENCE FROM THE DISTRIBUTION OF PRESSURE ON A BODY MOVING IN A FLUID.

Dryden[15] has recently reported some data on the distribution of pressure over the surface of a cylinder placed in the wind tunnel. His results qualitatively bear out in a remarkable way the theme of this article. The curves of Fig. 26 are taken from Dryden's paper. The pressure is at a maximum immediately in front of the cylinder, decreasing to either side for an angular distance of about 38°, where there is no change from the static pressure found in the wind tunnel in which the experiments were made.

The pressure drops below the static pressure from 38° to 180°. If this cylinder had been readily deformable its shape should certainly be expected to be altered in a manner already indicated. It is interesting to interpret in the light of these data the shape of icicles which was noted above. If the icicle be a cylinder any film of water present will be pressed away from the front to the rear. The exact shape that the film will take on will be determined by the equilibrium between the wind forces and those of surface tension and adhesion. Icicles are very frequently formed on the eves of dwellings by the trickling of the water over existing forms. Such shaping of the icicle, however, may be expected to take place under conditions where the wind can act merely as corroding agent. It may be pointed out further that the phenomenon of regelation may lend itself as a factor in the reshaping of the icicle when the temperature is 0° C.—the ice melting at points of highest pressure and recongealing at points of lower pressure.

If more data such as that given by Dryden were at hand, showing how the pressure changes with change of shape, one might formulate the relationship between the velocity, size, and resulting shape of the body. However, the principle of streamline assumption suggests a means of determining the stream-line shape for any condition of streaming. Such a method would be of importance in determining the proper entrance and the proper run of boats, torpedoes and shells. Likewise, a method of recording the relative distribution of pressure over an immersed body is suggested—the body being deformable as a soap bubble, with known forces of restitution.

[15] *Bul. Bur. of Std.*, 16, p. 489, 1920; or *B. S. Sci. Pap. No. 394*, Air Forces on Circular Cylinders. References to earlier data of the same kind are given in Dryden's paper.

No theoretical considerations seem to have been made to predict the distribution of pressure, such as is given in Fig. 26, for a cylinder. Yet it should be possible to make some prediction for simple cases. If it is assumed that the stream of air consists of spheres impinging upon the cylinder, and having a certain average momentum then the pressure at any element of the cylinder will be determined by the momentum imparted to or taken from the spheres in the immediate neighborhood of the cylinder normal to its surface.

It might be expected then that the pressure will be a maximum immediately in front of the cylinder decreasing to either side, first, on account of obliquity between the elements of surface and direction of the stream; second, on account of the fact that the spheres which have already lost some momentum must be swept along with the stream

The general outline of this paper and the experiments on the shape of the mercury drop were made while I was associated with the National Bureau of Standards. More extended experiments on the shape of drops was contemplated there. I recall with much appreciation the friendly criticism of Dr. L. J. Briggs and Dr. H. L. Dryden.

SUMMARY.

Evidence has been assembled to show that any deformable body moving in a fluid or immersed in a moving fluid will assume a shape that is as nearly as is possible "stream-line."

Illustrations of this principle of "stream-line" assumption are taken from geology, meteorology, physics, and biology.

The adjustment of organisms in accordance with this principle is very similar to the adjustment by organisms to directed light (heliotropism) and to gravity (geotropism). Accordingly a term is suggested for defining this adjustment, *viz.*, rheotropism.

CLEVELAND, OHIO,
August 12, 1921.

Surface Tension of Water and of Benzene.—SAMUEL SUGDEN (*Jour. Chem. Soc.*, 1921, cxix, 1483–1492) has re-determined the surface tension of these liquids against air at a temperature of 20.0° C., by measurement of their rise in capillary tubes. The surface tension of water was found to be 72.70 dynes per cm., that of benzene 28.85 dynes per cm.

J. S. H.

DATA PERTAINING TO VISUAL DISCRIMINATION AND DESIRED ILLUMINATION INTENSITIES.*

BY

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Laboratory of Applied Science, Nela Research Laboratories.

NOT many years ago the appraisal of the results of a lighting installation was based largely upon the distribution of illumination intensity upon a so-called horizontal working plane. However, during the past few years the science of illumination has progressed considerably through a much broadened viewpoint, resulting in a more extensive analysis of lighting. Gradually other factors were studied, such as contrasts, illumination intensities on various planes, and the distribution, color and spectral character of light. More recently attention has been directed to various psychophysiological factors such as speed of visual discrimination, the influence of color of light, and the effects of higher intensities of illumination. However, only a beginning has been made in investigating the unknown factors and even many apparently commonplace questions are still unanswered. In the present paper brief discussions are presented of the results of investigations of two phases of visual discrimination, both of which involve intensity of illumination.

In the first investigation the relation of intensity of illumination to the speed of visual discrimination was studied. One of the aims of the work was to develop a method of test which would provide a measure of the influence of intensity of illumination upon this factor without requiring a summary of data; in other words, to devise a "direct-reading" apparatus. A number of test-objects were used such as lines of various kinds, letters and other characters, and different styles of reading matter. The contrast in the test-objects was chiefly that resulting from black ink on white paper, but later this contrast was reduced in the case of the most successful reading test-object (reading matter in Old English type) by decreasing the reflection-factor of the paper. A large number of observers was used.

*Communicated by Mr. Luckiesh.

In the second investigation the aims were chiefly to determine the intensities of illumination chosen by various observers for reading amid an ordinary environment and to compare in this respect illuminants differing widely in spectral character. The test-object was ordinary reading matter having a contrast resulting from black ink upon white paper, and also from black ink on a dark gray paper. The two light-sources were respectively a gas-filled tungsten lamp and a mercury (glass tube) arc. Among other things, the influence of the maximum available intensity of illumination upon the chosen intensity was studied. A large number of observers was employed.

SPEED OF VISUAL DISCRIMINATION AS A FUNCTION OF INTENSITY OF ILLUMINATION.

Many data pertaining to the psychophysiology of vision show that most of the powers of the eye increase with increase in intensity of illumination within certain limits. The recent experiments conducted by Ferree and Rand [1] indicate that certain specific functions, such as speed of discrimination, ability to sustain clear seeing, etc., increase rapidly at the general level of illumination commonly encountered in interior lighting.

In the present investigation an attempt has been made to determine the combined effect of the increase with intensity of illumination of such functions as speed of discrimination and ability to sustain clear seeing, as evidenced by increased efficiency in certain lines of activity in which these visual functions play an important part, with the hope of showing the influence of intensity of illumination upon production in which visual discrimination is involved. The tests were suggested by various processes found in the industries.

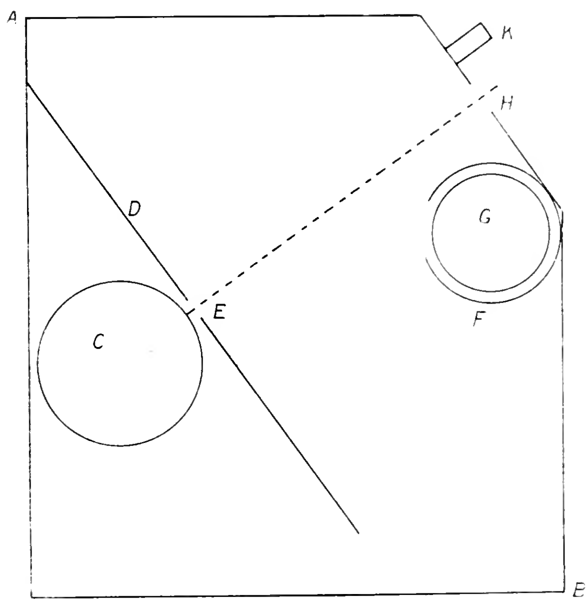
Eventually, after using various test-objects, the central idea was to have an observer read aloud from a column of reading matter attached to a revolving drum, the speed of which he adjusted to correspond to his highest rate of reading under a given intensity of illumination. A screen with a horizontal slot at the centre, placed in front of the drum, concealed from view everything excepting three or four lines of the reading matter, so that when the speed of the drum and the observer's highest rate of reading did not agree, his reading would be intercepted by one

[1] *Trans. I. E. S.*, xv, 1920, p. 769.

or the other edge of the slot. Measuring the speed of the drum when properly adjusted gave a means of ascertaining the rate of reading at different intensities of illumination. Reading aloud required continuous mental and physical activity on the part of the observer, who need not be in any degree accustomed to scientific observation in order to be a satisfactory observer.

Fig. 1 shows the general arrangement of the apparatus. The apparatus was contained in a box or booth, AB, 23 inches high, 21

FIG. 1.



Apparatus for speed of discrimination tests.

inches deep and 18 inches wide as shown in side view. A drum, C, 6½ inches in diameter, was driven through a suitable reduction gear by means of a small motor. The speed of the motor was varied by a sliding rheostat conveniently placed on the front of the booth, and was indicated by the "miles per hour" scale of an automobile speedmotor which was attached to the motor by a section of flexible cable.

The observer viewed the drum through a slot, H, near the top of the box which was provided with head-rest, K, and shields at the sides to eliminate extraneous light. The distance, EH,

from the drum to the observer's eyes was sixteen inches. The drum and mechanism were concealed from view by a screen, D, placed in a plane tangent to the surface of the drum and perpendicular to the line of sight.

The screen had at the centre a horizontal slot, E, ¼ inch wide and 3 inches long, exposing a portion of the test-object on the drum.

The source of light was placed so as to illuminate the central portion of the screen uniformly, and to avoid glare. In order to maintain a constant quality of illumination the use of a rheostat to secure variations in intensity was avoided. The illuminant, a 75-watt gas-filled tungsten lamp, was placed in a glass cylinder, G, 8½ inches long and 4¼ inches in diameter, which had a non-selective white diffusing surface. The axis of this cylinder was parallel to the axis of the drum, C. A series of wedge-shaped strips of tinfoil, of length a little less than the circumference, were pasted around the cylinder with their bases on a common element of the surface. The remainder of the circumference was completely covered with tinfoil. The whole was enclosed in a sheet-metal cylinder, F, having in it a longitudinal slot about 1½ inches wide, and as long as the diffusing glass cylinder.

By rotating the cylinder about its longitudinal axis the area of luminous surface exposed by the slot in the sheet-metal cylinder would be varied, with a resultant variation in the intensity of illumination on the test-object. A knob with a pointer and dial was provided at the side of the booth for rotating G and for reading the intensity of illumination after the calibration was made.

This type of variable source gave a uniform illumination over a sufficiently large area of the screen; it varied the intensity of illumination of the test-object from zero to 25 foot-candles; and it could be accurately calibrated and maintained constant.

Several kinds of test-objects were devised and used in the preliminary tests. Among them were sets of parallel lines, geometrical figures, isolated letters and numbers, which were allowed to flit rapidly past the slot in the screen. The observer was required to reduce the speed until he was just able to distinguish the characters. Here the motion of the test-object affects its discriminability, as is shown by the fact that if the characters on the drum consist of circles with a break in the circumference,

the break is more easily seen when at the top or bottom of the circle than when at the side. In the reading test, the motion of the drum is so slow that this effect is not present.

It is true that the speed of reading reaches a limiting value depending on factors other than speed of discrimination, and in order to make it a criterion of the latter, it is necessary to keep below this limiting value. Reading matter in ordinary type was found to be unsuitable as a test-object, because the limiting speed is reached very soon after the visibility of the test-object becomes great enough to discriminate it at all, even if very small type is employed. It appears that the form or outline of the word taken as a whole plays an important part in the recognition of familiar words printed in ordinary type. Old English type has the advantage of eliminating these characteristic outlines. The individual letters also contain more detail than those of ordinary type so that close discrimination is necessary to read it.

The test-object finally selected had the following qualifications: The type was exceptionally clear-cut and uniform Old English. The material was in the form of narrow columns without paragraph indentations. It contained no uncommon words and the subject-matter was such as would not require unusual thought or concentration on the part of the reader.

Photographic copies of the original were made, the size of the type being reduced to about that of 8-point ordinary type. The columns were 1¼ inches wide and were pasted end to end on the drum so as to form continuous columns of reading matter around it. Two such columns provided enough new material for a complete test.

In many industrial processes where speed of discrimination is an important factor, the extreme contrast of black on white is seldom encountered. Probably in many cases the greatest diffuse reflection-factor would not exceed 20 per cent. It accordingly seemed that the results of the test could be made to apply more closely to actual processes by reducing the contrast of the test-object.

Two series of tests were run, in one of which the coefficient of reflection of the background of the test-object was 80 per cent. (white) and in the other 22½ per cent. (a neutral gray produced by fogging the photographic prints). The screen, D, which filled practically the entire visual field, was matched to the back-

ground of the test-object in each case. For 80 per cent. reflection it was covered with white blotting paper, and for $22\frac{1}{2}$ reflection with a neutral gray paper with a matte surface.

Observations were taken at four different intensities of illumination. For the low-contrast test-object these were 3.12, 6.25, 12.5 and 25 foot-candles at the screen, D, and for the high-contrast test-object 0.39, 1.56, 6.25, and 25 foot-candles.

There are other factors besides intensity of illumination which might, if not eliminated, have an influence on the speed settings of an observer. Inferring that he was expected to increase his speed at the higher intensities, he might do so voluntarily if there were any circumstance which furnished him a means of comparing his different settings. Accordingly the speedometer was located so it could not be seen while making observations. The noise of the mechanism which might possibly form a criterion was reduced to a minimum through the use of rubber pads. The possibility of basing the settings on the position of the rheostat slider was eliminated in that a second rheostat, in series with that operated by the observer, was provided at the side of the box, and after each setting its resistance was altered in a haphazard manner.

Two other important considerations in determining the procedure are the state of retinal adaptation of the observer and the effect of increasing familiarity with the Old English type. A prolonged period of adaptation is of overwhelming importance when the level of illumination is near the lower limit of visibility or when the eye is successively subjected to widely different intensities.

In the present case the general level of intensity was that of a well-lighted interior, which was that to which the observers were adapted before commencing the test, while the intervals between the different levels of intensity employed in the test were very small as compared with the total range of intensities under which the eye is called upon to function. A period of three or four minutes was allowed for adaptation at each intensity. The observer was simply permitted to read until his reading became constant and the speed of the drum had been correspondingly adjusted.

In order to minimize the effect of increasing familiarity with the type, two settings at each intensity of illumination were taken. The test was begun at the lowest intensity and the illumination was increased by steps to the maximum value, and then brought

back to the starting point over the same route. An actual determination of the rate of reading as a function of the time at constant intensity of illumination (12.5 foot-candles) for several observers who were unfamiliar with the test-object showed very little increase after the first minute or two, after which time the relation was approximately linear, so that the above procedure would practically eliminate this factor from the results. The speedometer was carefully calibrated in terms of revolutions per minute of the drum.

Data from 49 different observers were obtained with the low-contrast test-object, and 37 observers with high-contrast object. Nearly all the observers in the second series had participated in the first series, but this could have little effect on the results other than to further minimize the effects of the "learning curve."

In most cases the speed settings on the return trip were higher than on the initial trip, as might be expected from the above considerations. The results showed wide differences between individuals both as to absolute speed of reading and relative increase of speed. Ferree and Rand found that slight defects of refraction of the eye cause speed of discrimination to increase more rapidly with intensity of illumination, a fact which in part accounts for the differences between individuals. To show the sort of agreement obtained between individual observations, the results for two observers, which may be regarded as typical, are included.

TABLE I.

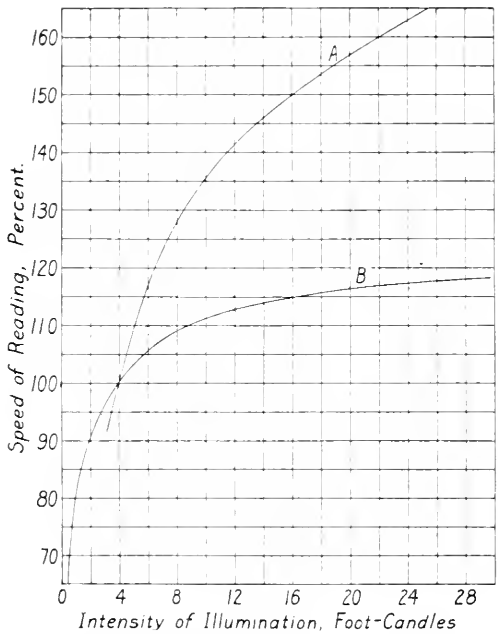
Observer	Intensity of Illumination Foot-candles	Speed Settings, Illumination Increasing (Read down)	Speed Settings, Illumination Decreasing (Read up)	Average
F. W. P.	3.12	17.5	26	22
	6.25	26.5	30	28
	12.5	33.5	32.5	33
	25	38	40.5	39
E. P.	3.12	11	12	11.5
	6.25	13	15.5	14.5
	12.5	17.5	19	18.5
	25	22	21.5	22

In order to obtain an average of the results the speed at 6.25 foot-candles for low contrast and 1.56 foot-candles for high contrast for each individual was set equal to unity.

Fig. 2 represents the mean results of all observations, plotted against intensity of illumination at the test-object. For both the low-contrast and high-contrast tests the speed at 4 foot-candles is taken as 100 per cent.

Fig. 3 shows the results plotted against the brightness in millilamberts of the background of the test-object. Here the speed at a brightness of 1.5 millilamberts is taken at 100 per cent. in

FIG. 2.



Effect of intensity of illumination on speed of reading. A, low-contrast test-object. B, high-contrast test-object.

both cases. It is seen that when speed is plotted against brightness of background, the test in which the background had the low reflection-factor still shows a greater relative increase. This was to be expected from the fact that the contrast was actually lower in this case, since the type face reflection-factor was approximately equal for the two test-objects.

The results show an average increase in speed of reading of 64 per cent. for the low-contrast test-object when the intensity of illumination was increased from 4 to 25 foot-candles and indicate

that the maximum speed had not been fully attained at the higher intensity. For the high-contrast test-object the average increase was 17 per cent. between the same limits and the curve approaches horizontal at 25 foot-candles.

TABLE II.

Data for Figure 2.

Intensity (Foot-candles)	Speed of Reading, per cent.
High-contrast test-object	
0.39	65.1
1.56	87.1
6.25	106.3
25	117.6
Low-contrast test-object	
3.12	91.8
6.25	119.0
12.5	142.8
25	164.3

TABLE III.

Data for Figure 3.

Brightness of Background	Speed of Reading, per cent.
Low-contrast test-object	
0.75 millilambert	77
1.50	100
3.0	120
6.0	138
High-contrast test-object	
0.33	73
1.33	97.5
5.33	119
21.32	131.5

ILLUMINATION INTENSITIES DESIRED FOR CONTINUOUS READING UNDER TWO ILLUMINANTS DIFFERING WIDELY IN SPECTRAL CHARACTER.

Some years ago Bell,[2] Luckiesh,[3] and others studied the effect of the spectral character of light upon visual acuity. The results of their researches showed that, owing to the chromatic aberration of the eye, visual acuity increased in general as the spectral character of the illuminant approached monochromatism. However, this result was obtained for details of the smallest size visible; in other words, at the limit of visibility.

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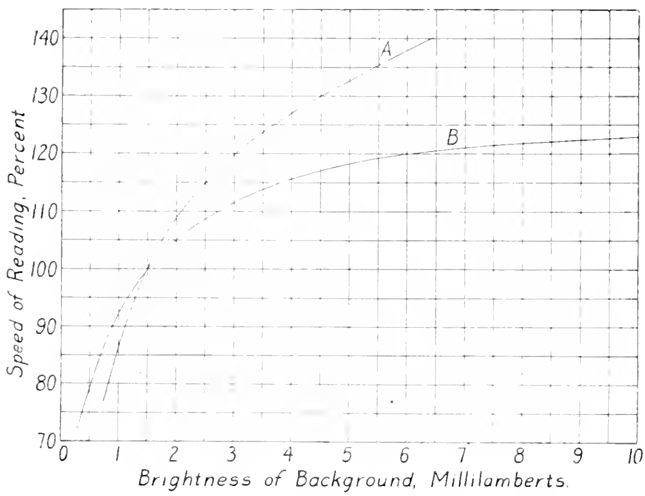
[2] *Electrical World*, May 11, 1911; Sept. 9, 1911.

[3] *Electrical World*, Aug. 19, 1911; Nov. 18, 1911; 62, 1913, p. 1150; *Trans. I. E. S.*, 7, 1912, p. 135.

It is well known that visual acuity does not increase as rapidly with increase of intensity of illumination for the level of intensities ordinarily used for reading, etc., as for lower levels of illumination. Furthermore, there is a general tendency to overlook the fact that seldom are the eyes called upon to distinguish objects of a size approaching the limit of visibility. Even in reading it has been shown by various investigators that the eyes are not concerned with visual acuity in the sense of limiting values. For example, type is commonly much larger than the smallest which may be distinguished under usual conditions, and any advantage

FIG. 3.



Relation between brightness of background and speed of reading.

in "revealing power" possessed by one illuminant over another for details of the smallest size which are visible decreases as either the size of the details or the intensity of illumination increases.

There are also interesting aspects which pertain to the eye and to its performance when engaged in seeing. It is well known that fine details can be distinguished only when looking directly at them. In other words, visual acuity is high for the central portion of the retina (the fovea), but it rapidly diminishes for areas beyond this region. In reading, it has been well established that the eyes do not scan each letter or even each word. The point of fixation progresses by a series of "jumps" along a line of type and experiments show that the number of "jumps" varies usually

from about two to seven for ordinary lines, say four inches in length. This is proof that visual acuity cannot be exercised in the ordinary sense in reading under usual conditions.

The chromatic aberration of the eye is easily demonstrated by viewing a line spectrum focused upon a ground glass. Ordinarily the normal eyes are focused upon reading matter at a distance of about twelve to fourteen inches. A yellow or green line in the spectrum can be easily and distinctly seen at about this distance; on the other hand, the blue and violet lines in the mercury spectrum are easily focused by a normal eye at a distance of four or five inches, and cannot be focused at the normal distance. The phenomenon is not so marked at the red end of the spectrum because red spectral lines would normally be focused at greater distances than yellow lines.

These are interesting facts but after all there are so many subtle and intangible influences in lighting that the final test is that of actual practice. For this reason it appeared of interest to conduct some practical tests, under good conditions of distribution of light in an ordinary room (with light ceilings, buff walls and light oak finish and furniture), using observers generally unacquainted with such facts as are discussed in the foregoing, to determine the relative importance of some of these factors in actual practice.

The apparatus and method of procedure were changed two or three times during the tests, whenever it appeared that conditions could be improved, or tests under different conditions were desired. The specific changes made will be described later. Observers were obtained from the Research Laboratories and the Engineering Department, availability being the only requirement.

In the early part of the work gas-filled tungsten lamps (emitting light of an extended spectral character) were arranged in a white-lined box with a shutter in front. A similar apparatus was made up with a mercury-arc lamp (glass tube), emitting light approaching monochromatism. The observer was seated at a table in an office and read a book on the table in front of him. The illumination, received over the left shoulder from the lighting units placed above and behind him, could be varied at will by the observer by means of strings attached to the shutters. Especial care was taken to avoid glare by specular reflection. When the illumination on the reading material was varied the illumination

TABLE IV.

Summary of Results af Reading Tests.

Test No.	No. of Observers	Max. Illum. Obtainable.	Foot-candles Chosen by Group: Mercury Arc, Mean Value	Mercury Arc, Median Value	Gas-filled Tungsten, Mean Value	Gas-filled Tungsten, Median Value	Ratio of Illumination Intensities Mercury Arc to Gas-filled Tungsten: Ratio of Means	Ratio of Medians	Mean of Individual Ratios	Median of Individual Ratios.	Prob. Error of Mean of Individual Ratios
1	*22	10 f. c.	6.3	6.5	5.3	5.6	1.19	1.16	1.20	1.20	±.030
2	55	30	14.2	13.5	12.7	12.3	1.12	1.10	1.17_5	1.14	.019
2a	24	30	11.8	10.5	10.6	9.6	1.11_5	1.09_5	1.16	1.15	.012
3	26	30	18.0	17.8	17.4	16.0	1.03_5	1.11	1.06_5	1.07	.014
4	24	45	16.9	16.2	16.1	14.7	1.05	1.10	1.10	1.04	.012

Test No.	READING MATERIAL
1.	*Trans. Illum. Eng. Soc.*, also "Life of Edison"
2.	*Scientific American Monthly*
2a.	" " "
3.	*Saturday Evening Post* (dyed)
4.	*Scientific American Monthly*

* Fifteen of these observers repeated, and their second observations have been given the same weight as different observers. The same observers were used in Tests 2a and 4. Results of 2a are included in 2.

of the walls and other objects in view varied in like manner. The maximum illumination of the reading material obtainable from each source was approximately ten foot-candles.

The reading material, chosen to be of the most probable interest to all observers, was a copy of the *Transactions of the Illuminating Engineering Society*, and another book with matte paper, "The Life of Edison." Each observer, when seated at the table, was told to adjust the illumination intensity to the value which he would consider necessary for comfortable reading, without eye-strain, for several hours. The idea which we attempted to convey was that the observer should not try to use the minimum possible illumination, but neither should he be wasteful of the light. The observer readjusted the illumination at the end of every five minutes for a period of one-half hour. Later in the day he repeated the observation, using the other illuminant. In working up results of the test the first setting by each observer was disregarded, as it was felt that the first five minutes were necessary for adaptation. Twenty-two observers took part in this test, and fifteen of these repeated their observations. In the test results given in Table IV the second observations by these fifteen have been treated as observations by other individuals.

Profiting by the experience gained in this test, some changes in conditions and procedure were made. Illuminants of the two types were suspended about five feet above a table placed in the corner of a large room. A fifty-inch glass mercury tube with reflector was used.

For about three-fourths of the observers in test No. 2 (Table I) the tungsten source was a large gas-filled tungsten lamp in a housing behind an opal glass disk about ten inches in diameter, screened by a cornu diaphragm. In order to make the two sources more nearly alike as regards diffusion a new tungsten unit was later prepared. Ten gas-filled tungsten lamps were placed in a white-painted box 15 x 36 x 9½ inches, the opening being covered with opal glass. Roller curtains were arranged with both illuminants to screen them to the desired amount, beginning at both ends of each. The position of the table was such as to avoid glare by specular reflection. The reading material used was a copy of the *Scientific American Monthly*. In order that all observers should receive the same instructions, written instructions as follows were given to each:

INSTRUCTIONS FOR READING TEST.

"The object of this test is to measure the intensity of illumination most satisfactory for continued use in reading. This does not mean an intensity with which it is just possible to get along, but rather one which seems comfortable and desirable.

"In commencing the test the observer will read for a period of four minutes under a selected intensity of illumination. He will then be instructed to adjust the light to suit his own taste, and in doing so will bear in mind the above-mentioned objective. At the end of each four-minute period the observer will be instructed to readjust the light."

The selected intensity referred to was in most cases four foot-candles. Observations with each source continued for sixteen minutes, one following the other immediately. Alternate observers were started with the tungsten source, others with the mercury-vapor. For the major part of this test the maximum intensity obtainable with each source was thirty foot-candles. Later a further test was made under the same conditions, with a maximum intensity of forty-five foot-candles with each source.

In order to determine the effect of reduced contrast in the reading material a copy of the *Saturday Evening Post* was dyed a dark gray, its reflecting power being almost exactly half that of the *Scientific American Monthly* which had previously been used. The maximum intensity obtainable in this test was thirty foot-candles.

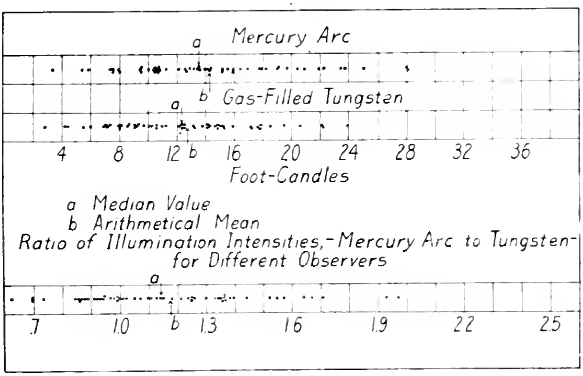
In most cases photometric observations were made by two or three observers. Each source had a scale indicating the shutter position, and calibration curves were determined. Constancy of illumination was checked frequently. The mercury arc was found to be variable in intensity when burned on constant voltage, but fairly steady when burned at constant current on a 230-volt circuit with extra resistance.

In tests of this nature results by different observers are likely to vary over a wide range. The result for a group of observers may be expressed in several ways, two of which are the arithmetical average and the median value, *i.e.*, the value for which there are equal numbers of observers above and below. The median has the advantage of not giving undue weight to observations which are far from the average. The results of these tests will be given in both ways, though in a few cases values by

one or two observers will be omitted from the summary because they deviate greatly from the average (this is justified by Chauvenet's criterion). Observations by three observers in one of the tests are omitted because they selected the maximum intensity available with one or both illuminants. This raises the question whether they properly understood the criterion of observation, or whether or not they might have selected a higher intensity had it been obtainable. In beginning this second test it was thought that thirty foot-candles should be ample for any observer.

A summary of results of the various tests is given in Table IV. A plot of the results of Test No. 2, which is typical of all the tests,

FIG. 4.



Average illumination intensities chosen by different observers for continuous reading under mercury arc and gas-filled tungsten lamps. (Test No. 2.)

is given in Fig. 4. The probable error of the mean of the individual ratios in each test, given in the last column of Table IV, has been computed by means of the laws of probability.

In Table V are given data regarding the reading materials used in the tests. The "apparent diffuse reflection factor" used in the table may be defined as the ratio of the brightness of the unprinted portion of the material, at the angle of view (about 30° from the normal), to the brightness of a perfect diffuser, having a diffuse reflection-factor of 100 per cent., receiving the same illumination. In order to convert this factor into brightness in millilamberts for an illumination of one foot-candle, it should be multiplied by 1.076.

TABLE V.

Data on Reading Materials Used in Tests.

Reading Material	Apparent Diffuse Reflection-Factor	Size of type	Lines per Inch
Trans. I. E. S.	84 per cent.	11 point	6
"Life of Edison"	89.5 per cent	12 point	5.6
Sci. Am. Monthly	80.5	9 point	7.2
Sat. Eve. Post (dyed)	*41	9 point	9
Sat. Eve. Post (dyed)	*42.5 for mercury-vapor light.		

* The dye used in dyeing the *Saturday Evening Post* was somewhat bluish, which accounts for the higher reflection-factor obtained for illumination by the mercury vapor lamp. If this correction was applied to the results in Table 4, all ratios for test No. 3 would be raised about 4%.

The visual acuity tests by Bell and by Luckiesh, referred to in the first part of this paper, indicated that at illuminations of the order of one or two foot-candles about 75 to 95 per cent. more light from tungsten lamps than from mercury arcs was required for equal revealing power of small details. The results of the tests reported here appear to show that visual acuity at low illuminations is not a proper measure of the usefulness of a light for clerical work. In fact, the average observer desired from five to twenty per cent. more illumination from the mercury arc than from tungsten lamps, and in no case did the average ratio for a group of twenty or more observers fall below 1.04.

The actual intensity desired by the average observer is not so definitely determined but appears to be from ten to seventeen foot-candles for ordinary reading matter when a high intensity is available.

Attention is directed to the fact that in test No. 4, which was identical in nature with No. 2a, except that the maximum intensity obtainable was 50 per cent. greater, the average intensities chosen were very closely 50 per cent. greater than in test No. 2a. However, the ratio of mercury to tungsten illumination was not greatly changed. It would be of interest to determine the maximum intensity which the average observer would choose if the available intensity was unlimited, but unfortunately lack of apparatus to obtain still higher intensities precluded the performance of such a test.

The authors desire to express their appreciation to all the observers who participated in the tests, and especially to the Engineering Department, which furnished approximately half of the observers.

CLEVELAND, OHIO,
JULY 21, 1921.

PHYSICS A HUNDRED YEARS AGO.*

BY

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A CENTURY ago science had recently lost three eminent men who had notably advanced our knowledge of electricity, dynamics and heat, Cavendish (1731–1815), Rumford (1753–1814), Watt (1736–1819).

The steam engine had appeared and was used for pumping mines, for locomotives and for the propulsion of ships; the notable discovery had been made, to quote the contemporary words of John Herschel, "A man's daily labour is about four pounds of coal." "Two pounds of coal would raise a strong man from the valley of Chamounix to the top of Mt. Blanc." "You can raise seventy million pounds weight a foot high by a bushel of coals." [1]

There had just begun that industrial revolution due to the use of coal and iron, which, for better or worse, has in a century transformed the world.

Every age regards its progress with a wholesome and justifiable pride. The achievements of preceding generations are dimmed in lustre by familiarity. The imagination is too feeble to form an adequate conception of the marvels awaiting discovery, ready to fall like ripe plums into the laps of successors. On the other hand, recent discovery always stands out with a delightful and refreshing vividness.

Now a hundred years ago people were thoroughly pleased with their discoveries, no less than we are to-day. It is sufficient to mention such successive discoveries as the spinning jenny (1768), spinning frame (1769), cotton gin (1792): the discovery of the planet Uranus (1780), the first air balloon (1783), and vaccination (1796).

Thanks to Newton and others, it was a just claim, in 1821, that more scientific progress had been made in the preceding two hundred years than in the whole previous history of mankind.

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* Address at the Centenary Reunion of McGill University.

[1] The actual work done by a bushel of coals used in a steam engine was called its *duty*, a useful term.

It is curious to read moreover the lamentations by Thomas Young on the enormous amount of scientific literature and the great variety of publications, which rendered it difficult or impossible to keep abreast with scientific discovery. How seriously has this evil increased during the past hundred years, until we seem doomed to be buried under our own records! And this trouble must continually increase with time.

Mr. James McGill was an enlightened citizen of Montreal with an interest in literary and scientific progress. It requires but a small stretch of the imagination to conceive of our founder sitting under an elm tree on Burnside Farm by the side of that little brook, with its rustic bridge and lovers' walk, which flowed past the spot where the Macdonald Physics Building now stands. The valley of that brook is still visible in the back lane and tennis court. And indeed in spring time, the brook itself revives and floods our basement.

Imagine him seated there and reading the following fictitious letter supposed to have been written about a century ago by a friend of James McGill, an imaginary professor of natural philosophy at the famous University of Glasgow, giving an account of a visit to London and Paris, and describing to our founder what he saw which was new and interesting in the scientific field. It is a matter of regret to me that I cannot read this letter to you in the good Scots tongue.

From Professor Robin Angus,
The University of Glasgow,
(Undated).

To Mr. James McGill,
of Montreal.

Dear Mr. McGill,

I am now fortunate in writing to you to give my promised account of a long projected visit to London and to Paris, and my description of the progress of recent discovery in natural philosophy.

I left Glasgow on the first of June and the roads were in good condition so that we made a swift and agreeable journey. One day indeed we traveled 59 miles in 11¾ hours, including time for baits!

On my arrival at London I quickly went to the Royal Institution and called on Dr. Thomas Young. I was fortunate enough to hear one of the 93 lectures which he is giving on natural philosophy. These lectures are shortly to be published as a book, a copy of which I will send you. His lectures were well illustrated by skilful experiments.

You are aware that Sir Isaac Newton suggested that light consisted of little bodies or corpuscles shot from the source of light traveling "with an eel-like motion" along straight lines. Now Dr. T. Young will have none of this theory, but he agrees with Huyghens that light travels with wave motion in some subtle and all pervading medium which is called æther. Huyghens thought that light consisted of waves with a motion of the æther to and fro in the direction in which light traveled, but Doctor Young points out, as did Newton, that light may be "one-sided" or polarized, so that it is essential to believe that the vibrations are transverse or perpendicular to that direction in which light moves. As indeed the French philosophers have very clearly proved.

Doctor Young has a large trough with a glass base, filled with water, illuminated beneath; and with a large mirror he projects upon a white screen the waves which are made upon the water by one or more pointers fastened to vibrating rods. In this manner he illustrates very clearly what is called the interference of light, well enough known to Newton, but a stumbling block to his corpusular theory.

At the Royal Institution I met also with Sir Humphrey Davy, who has saved countless lives of miners by his safety lamp, where the flame is surrounded by fine wire-screen, preventing premature explosion.

The great Corsican ogre, Napoleon, scourge of the world, is newly dead. Yet in fairness it must be stated that he proved a good friend to science. In the midst of the war between England and France he gave, in spite of strong opposition, a great scientific prize to an Englishman, Davy, for his discovery of potassium and of sodium by electric separation. He caused a galaxy of scientific men to gather at Paris, and encouraged them in their work by every means at his disposal. Napoleon was a man who certainly knew that in science, too, "As a man sows, so shall he reap."

I met at the Royal Institution a young assistant of Davy's named Faraday who was full of insight and enthusiasm so that

he promises to go far. He was greatly interested in electrical experiments.

You are familiar with electrical machines and Leyden jars, lightning rods and Franklin's experiment with the kite, and how he obtained electricity from the clouds. All these are well described in a little book by Doctor Priestley [2] which I sent you last year. But, as the Hon. Mr. Cavendish wrote, "It must be confessed that the whole science of electricity is yet in a very imperfect state"; or to quote my friend Doctor Young (p. 507), "The phenomena of electricity are as amusing and popular in their external form as they are intricate and abstruse in their intimate nature."

Suddenly there has come from Denmark a great burst of light, which we owe to Hans Christian Oersted. This illustrious man was born in 1777, and after passing with honours at school he received *free* residence and a small scholarship awarded to needy students. [3] After a distinguished career at Elers College he received a Cappel Traveling Fellowship which enabled him to visit the leading scientific men in Germany and France to his great benefit as it now proves to ours.

This plan of helping able students to secure a good university education, and to visit other countries in order to appreciate scientific progress, has much to commend it to other countries and to all universities.

Many philosophers have endeavoured to deflect a magnet with electricity, using an electrical machine with open circuit. Now Oersted was lecturing to his advanced students and he discovered, his class being there and then assembled, that with an electric battery and a closed circuit he could cause a current of electricity to deflect a magnet. Not when the wire is perpendicular to the needle, but when parallel. This influence will pass through wood and water and mercury and metal plates, excepting iron, so that the influence of the electric current on a magnetic pole is as it were in circles around the wire. Already Schweigger, at Halle, has invented a measurer of electric current called the Astatic galvanometer, where two equal magnetic needles pointing opposite ways have

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[2] "A Familiar Guide to the Study of Electricity," 4th ed., 1786. (J. Johnson, London.)

[3] *Nature*, p. 492, 16 June, 1921.

been deflected by a current passing in a coil of wire round one needle, a most sensitive arrangement.

Davy, using the great battery of 2000 cells of zinc and copper at the Royal Institution, has passed an arc between two carbons giving a most brilliant light. Now this arc he has deflected with a magnet, showing that as a current in a circuit will deflect a magnet so will the magnet deflect the circuit if and when a current passes in it. Here then we have another example of the third law of Newton that "action and reaction are equal and contrary." Nay! Oersted himself hung up by a fine wire a small battery and coil and deflected it with a magnet. Hence we now have a new branch of science, my dear Mr. McGill, which we may call electrodynamics or electromagnetics. The great M. Ampère at Paris has made vast strides in this new subject.

And indeed I must pass over much that I would wish to tell you that I saw and heard in London, and proceed with my visit to Paris, which I reached safely after a troubled crossing over the Channel.

In spite of the recent wars, most cordial relations have speedily returned between scientific men of all countries.

I have met M. Ampère who, stimulated by Oersted's discovery, has extended it and proved that "two parallel and like-directed currents attract each other, while two parallel currents of opposite directions repel each other."

It may be truly said that "the theory and experiment (of electric currents) seem as if they had leaped full-grown and full-armed from the brain of the 'Newton of Electricity.' The theory is perfect in form and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced and which must always remain the fundamental formula of electrodynamics." [4]

But I must pass on, my dear Mr. McGill, to other branches of natural philosophy. I must name the illustrious M. Chladni, whom they call "the Father of Acoustics." Him Napoleon summoned to show his experiments on sound and gave a grant of money towards the publication of his book. Galilei first experimented with dust on vibrating metal plates struck by a chisel, but Chladni made great improvemnts by using lycopodium dust with sand. He separated thus the quiescent from the turbulent regions.

[4] Maxwell.

for as Faraday has explained, the light lycopodium dust is caught in the whirlwinds of air and finally comes to rest below them, while the heavier sand is driven to the nodes. I have been informed that in the recent wars sand has been placed on a drum and the direction of underground mining has been found by the displacement of the sand on the top of the drum set vibrating by the distant blows on the ground of the picks of the enemy. An ingenious application of Chladni's figures!

Most interesting of all are the speculations about light founded on the most ingenious experiments carried out by Fresnel and Arago. They experiment with "one-sided" or polarized light and secure interference between two rays from the same source polarized in the same plane, which cannot be done when the rays are polarized at right angles. This is strong evidence for the wave theory, but a challenge was given that a small round body like a coin should have a bright spot in the center of its shadow from a small bright source of light. In truth, and it should! And the difficult experiment was triumphantly carried out by M. Fresnel!

Beautiful and interesting experiments have also been carried out by M. Malus on the polarization of light, and splendid colour effects have been achieved with the interference of polarized light passing through crystals of mica, gypsum, or quartz.

The simplest interference experiment is to pass light through a slit and hence through two slits close together. On a screen behind you can perceive bright and dark bands alternating which prove that two lights can make darkness, which seems impossible with material things, but is readily explained with waves, for we have all seen, on a lake or pond, crests and troughs of waves cancel one another.

There is great encouragement given to science in these days. Thus the famous Euler received a grant of £20,000 in the last century, and the British Government offered a prize of £20,000 for finding the longitude at sea within thirty miles.

Space has not permitted me to write of Fourier, a great mathematician who has established most fundamental principles of the flow of heat. His work, "Théorie de la Chaleur," has in his own lifetime passed into a classic.

But what shall I say of Laplace, author of "Mécanique Céleste," now seventy years old, comparable only with Newton, who has been honoured by all political parties in the turbulent

periods passed by France in his long life. A man more admired than loved perchance! Laplace has advanced the theory of tides, explained the origin of the sun and planets from a nebula to its present state, and proved that all bodies of the solar system are stable, and may have been so for periods of vast antiquity.

In the spectrum of the sun, Wollaston (1802) and Fraunhofer (1815) have found a very great number of dark lines which await explanation from succeeding generations. Here indeed we have a great mystery!

But I fear, dear sir, that my letter has far outstripped your patience. Your friends in Glasgow and in Scotland learn with pleasure and interest your scheme for founding a College for the Advancement of Learning in Montreal. Judging from what I have seen in Scotland, in England and in France such an institution may bring lasting lustre to your name, and yield priceless fruit throughout succeeding ages.

Believe me, honoured sir,

Your most respectful servant,

ROB. ANGUS.

It must be admitted that historically the above letter will be found wanting, for it purports to be written in 1821, by a " fake " professor of Glasgow University, whereas we all know that our founder died in 1813, eight years before McGill received its charter in 1821. I am assured, however, by my colleague, Prof. Cyrus Macmillan, that otherwise my conception of such a letter is a sound one, and that James McGill was truly interested in science as well as letters. He was himself a student or at least a matriculant of Glasgow University, a fact which explains so much. You will recall that he specially enjoined in his will that there should be a Professor of Natural Philosophy, until such time as there should be three chairs established in mathematics, natural philosophy and astronomy.

To-day McGill has many professors of physics, a subject now taught to all faculties. McGill has also several professors of mathematics, but no astronomer, although he whom we might venerate as our second founder, I name Sir William Macdonald, donated a splendid region on the summit of Westmount for an observatory, the land being still available, although we cannot hope for " good seeing " within the confines of a city yearly growing

blacker with factory and engine smoke, largely preventable and unnecessary.

As for the information conveyed in the fictitious letter, it is gathered mainly from contemporary sources, and the lectures by Dr. Thomas Young, afterward published as a Treatise on Natural Philosophy, are a great mine of information. But a more valuable source is Mrs. Kirstine Meyer's recent essay [5] on the Life of Oersted. For in 1801 Oersted went to Weimar, Berlin, Gottingen and Paris; he saw Ritter's electrical experiments and the very first storage battery, copper plates with damp cardboard between, which retained a charge for some time after it was connected to a battery, capable also of generating a current after being charged.

In 1812 and '13 Oersted again visited Berlin and Paris, and from autumn, 1822, to the summer of 1823 he visited Germany, France and England, although he was full professor of natural philosophy at Copenhagen at the time. I mention this because we see here in the same man the great advantages of three notable institutions or arrangements which I wish to advocate ardently for Canada and elsewhere. For in the case of Oersted we see an able but needy student obtaining free board and residence and a scholarship as well, relieving him of money embarrassments and securing him a sound and liberal education. Secondly, we find him with a traveling fellowship which enabled him to appreciate the work and progress of many scientific centres. Lastly, we find him with a sabbatical year, relieved from the burden of teaching and academic affairs, and given leisure to think and to investigate. The scholarships, the traveling fellowship, the sabbatical year were all fruitful. As a result Oersted founded electrodynamics, for he proved that a coil of wire with a current round it was the equivalent of a magnet.

This fundamental result, developed by Ampère, Faraday, Maxwell, and many other co-workers, is the seed of the fruitful results or harvest which you see around you to-day. I refer to electric motors, lamps, dynamos, generators, electric irons, cookers, bells, toasters, cleaners, and no less to telephones and telegraphs.

We can rest assured that if you give due encouragement and assistance to your quite ablest boys at schools, and to students and professors at universities there are other and greater conquests of

[5] See *Nature,* 16, June, 1921.

science of which we have little or no conception to-day, awaiting discovery and development, and that you must not hesitate to encourage pure research, at unpromising subjects even, rather than endeavor too much to secure industrial research on a commercial basis. The pioneer work is truly of the greater importance though less likely to secure the appreciation of manufacturers, of politicians, of practical men and of the public at large.

Here I must interpose a story. About fifteen years ago, one of my predecessors, Professor John Cox, gave a lecture in this theatre on the passage of electricity through rarefied gases combined with some wonderful experiments, all with the skill and eloquence of which he was and is still a master. Now Sir William Macdonald was present and he remarked afterward, "How beautiful and how useless!" Yet it is the study of those very phenomena which has led to most notable recent developments in radiology, for example the Coolidge tube, in long-distance and guided telephone, in wireless telephony and telegraphy, particularly by the use of the electronic valves.

But Sir William appears to have been himself a convert before his death. As donor to McGill of this Macdonald Physics Building, as founder of the two Macdonald chairs of physics, he was present at a lecture given by Sir Ernest Rutherford on some of his recent work on radioactivity, and after the lecture Sir William stated that "if all the money spent on the endowment of physics at McGill had produced no other result but Rutherford's work on radioactivity alone—the money would have been well spent!" That verdict you will all endorse, with a fervent hope that, although we can scarcely expect ever to rival that remarkable outburst at McGill, of a new branch of physics, we may not merely assist in the training of many thousands of young Canadians in the foundations of science, but also hand on the torch of original research and pioneer investigation in this place.

Oersted in 1822 and '23 was not very enthusiastic about German science. "Schweigger, at Halle, has brains, but is a reed shaken with the wind. His experiments are not of much importance; Kastner, at Erlangen, writes thick volumes compiled with much toil but without all judgment. Yelin, at Munich, makes indifferent experiments and lies much." (Really, really, Yelin, this is too bad!) "But I have found much that was instructive with Fraunhofer, at Munich, so that I have been able to occupy

myself with benefit there for about a fortnight." But he writes to his wife from Paris in February, 1823. "My stay here grows more and more interesting to me every day. The acquaintances I have made grow every day more cordial and intimate." He saw Biot, Fresnel, Poillet, Ampère, Arago, Fourier, Dulong and many others; such was the brilliant list of physicists there at work at Paris. He had long discussions with Ampère on his famous theory, still accepted, that magnetism consists of electric currents in the molecules—electron currents or oscillations as we should perhaps say to-day. Oersted adds, "On the 10th I was at Ampère's by appointment to see his experiments. He had invited not a few—he had three considerable galvanic apparatus ready; his instruments for showing his experiments are very complex; but what happened? Hardly any of his experiments succeeded. He is dreadfully confused and is equally unskilful as an experimenter and as a debater." This report is in strange contrast with the written records of Ampère which Maxwell has described as the work of the "Newton of Electricity," "perfect in form and unassailable in accuracy." Perhaps Ampère had had the best of an argument!

What then has been added in the last hundred years? Well, the answer to that question will depend on whether you are a so-called practical man or a theorist, whether you are most interested in the applications and practical achievements of physics or in the great principles and theories which underlie the theory and from which the practical applications necessarily arise.

The last hundred years have speeded up all human activities. It now takes days for matter to cross the Atlantic instead of weeks, as then; while messages are flashed across almost instantaneously. A hundred miles a day by coach or on horseback was a strenuous journey, a thousand miles a day by rail is to-day not formidable.

It has been argued with much force by R. A. Freeman in his "Social Decay and Regeneration" that mankind has suffered to a terrible extent by the great access of power which science has suddenly placed in its hands, and it may well be doubted if society is yet fitted to receive fresh gifts of energy from the hands of science. Moral development and social organization has lagged behind scientific progress. Human nature is stable and ill fitted to adapt itself to changes of the magnitude and variety of the last

three generations. The resultant instability of modern conditions has shown itself to the greatest extent where the attempted assimilation has been most rapid and ill digested. Petrograd stands out as a prominent and inconceivable wreck, through the mirage of a prostrate Russia.

When we turn our attention to the intellectual achievement of physics we see a far more attractive picture. The last hundred years have seen the almost complete development of the science of electricity.

The great principle of the conservation of energy established by the insight of Joule, Kelvin, Helmholtz and others, stands together with the Second Law of Thermodynamics as the main prop of all physical conceptions. The isolation of the electron, the discovery of its properties, experiments with alpha and röntgen rays and immense developments in modern spectroscopy are illuminating a vivid conception of the structure of the atom. The present century is responsible for the new branch of physics, and in this very place Rutherford delved deep and built high in radioactivity, and we are all gathered together at a "veritable shrine," already venerated as such. We are passing to a new outlook where energy becomes dominant, so that not only does matter appear to be energy, but space, linked with time from which it is inseparable, is regarded as a continuum of energy mainly.

Most important of all is our revision of fundamental conceptions on a more comprehensive scale, in accord with the general scheme of the universe of which we are denizens, embraced in the fascinating and far-reaching Principle of Relativity.

Those only who have specialized in modern physics are familiar with the strange elusive problems embraced in the Quantum Theories of Energy.

An atomistic theory of matter is easy to conceive. A corpuscle of electricity, now called an electron, with well-marked properties, electric and magnetic, is not too obscure. But bundles of energy, or quanta, of magnitudes varying with and proportional to the frequency of the propulsive electromagnetic vibrations present formidable obstacles to the human intelligence, and yet some such entities pervade modern research, and are to-day most fruitful of actual philosophical progress.

I wonder what my successor, lecturing here one hundred years hence, will be saying about relativity and about quanta!

Utilization of Nitre Cake. W. H. H. NORRIS (*Jour. Soc. Chem. Ind., Trans.*, 1921, xl, 208-212) describes a new process for the utilization of nitre cake. It is based upon certain phase relations. Nitre cake is treated, under definite conditions, with a solution containing sodium sulphate and ammonium sulphate; anhydrous sodium sulphate precipitates, and a strongly acid liquid is formed. The process is continuous. The mother liquor and washings, from the ammonium sulphate of the preceding cycle, have the following composition in pounds: Ammonium sulphate, 5800; sodium sulphate, 2295; sulphuric acid, 318; water, 5800. They are heated to a temperature of 90° C.; and 5550 pounds of granulated nitre cake are added. Anhydrous sodium sulphate weighing 3880 pounds precipitates, and 1670 pounds of sulphuric acid pass into solution. The liquid is diluted with 6700 pounds of water, and is used for the absorption of the ammonia produced by a gas plant. The resulting liquid is concentrated in a vacuum pan to remove 9300 pounds of water; 2240 pounds of ammonium sulphate deposit are collected, subjected to centrifugation, and washed. The combined mother liquor and washings are used for the treatment of another batch of nitre cake, and the entire cycle is repeated. The anhydrous sodium sulphate is of good color, contains 95 per cent. sodium sulphate, 0.04 to 0.15 per cent. sulphuric acid, and 0.24 to 0.39 per cent. ammonium sulphate; the washed salt contains less than 0.05 per cent. iron, and is of value in the manufacture of plate glass. The ammonium sulphate contains over 24 per cent. ammonia, and approximately 95 per cent. absolute ammonium sulphate.

J. S. H.

Physicochemical Study of Invertase.—The enzyme invertase, also called sucrase or saccharase, is a catalyst which produces hydrolysis of sucrose or cane sugar into invert sugar, an equimolecular mixture of *d*-glucose and *d*-fructose. The silver ion acts as a poison to this catalyst. H. VON EULER and O. SVANBERG (*Arkiv för Kemi, Mineralogi, och Geologi,* 1921, viii, No. 12, 1–13) obtained highly purified invertase by prolonged dialysis. They then determined, in the electrometric way, the dissociation constant of the silver derivative of the enzyme, and of the silver derivative of each of the following compounds, all of which are closely related to the nucleoproteins: Guanylic acid, inosinic acid, adenylic acid, guanosin, adenosin, caffeine, guanine, and uric acid. Their results indicated that a complex group, which contains phosphorus and is similar to the complex groups found in the nucleoprotein molecule, is present in invertase. This conclusion was supported by the fact that the invertase preparation did not contain sufficient bases to combine with its phosphoric oxide, hence the latter must exist in organic combinations.

J. S. H.

A STUDY OF SEWAGE AND TRADE WASTES AT BRIDGEPORT, CONNECTICUT.*

BY

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Bureau of Chemistry, U.S. Department of Agriculture.

INDUSTRIAL wastes and sewage of cities and towns along the Atlantic seaboard usually are disposed of conveniently and at least expense by discharging them without treatment into adjacent harbors or the estuaries of rivers. The practice is of long duration and has become more or less established as a right of manufacturing establishments and of cities situated along the Atlantic coast.

While the uncontrolled dumping of untreated sewage and trade wastes into bays, harbors and estuaries along the coast is an inexpensive and natural method of disposal, marked disadvantages of this custom are becoming apparent. Among these are the gradual conversion of naturally beautiful harbors and estuaries into discolored and foul-smelling pools, the interference with sports and recreation along the shores, and, what is more important in the economic life of the nation, the destructive effect on fish and shell fish life, thereby affecting seriously the natural yield as well as possible future development of an important food supply. Where questions of expense and convenience are involved, esthetic sentiment does not receive the consideration which it perhaps deserves. It is difficult to arouse general public interest in a project to keep our waterways clean when the argument is based primarily upon esthetic considerations and when the true economic possibilities can be proven only indirectly, or must be assumed.

The destructive effect of industrial wastes on fish and shell fish life is, however, a very practical problem. Oysters are said to spawn more vigorously in the protected, shallow, warmer waters of the unpolluted harbors and estuaries of the rivers than they do out on the open beds, while the polluted water from some of the harbors, we are informed by the Bureau of Fisheries, will

* Contribution from the Water and Beverage Laboratory, Bureau of Chemistry, U. S. Department of Agriculture. Communicated by Dr. Skinner.

cause the death of oyster larvæ almost at once when placed in it. The effect of the wastes on the migration and spawning of fish is also said to be of importance. These factors are gradually receiving increased attention, and the question of the exercise of some sort of control over the disposal of sewage and industrial waste is being raised more frequently by those interested in the conservation of our natural food resources.

BRIDGEPORT, CONNECTICUT, HARBOR; AND YORK RIVER, VIRGINIA.

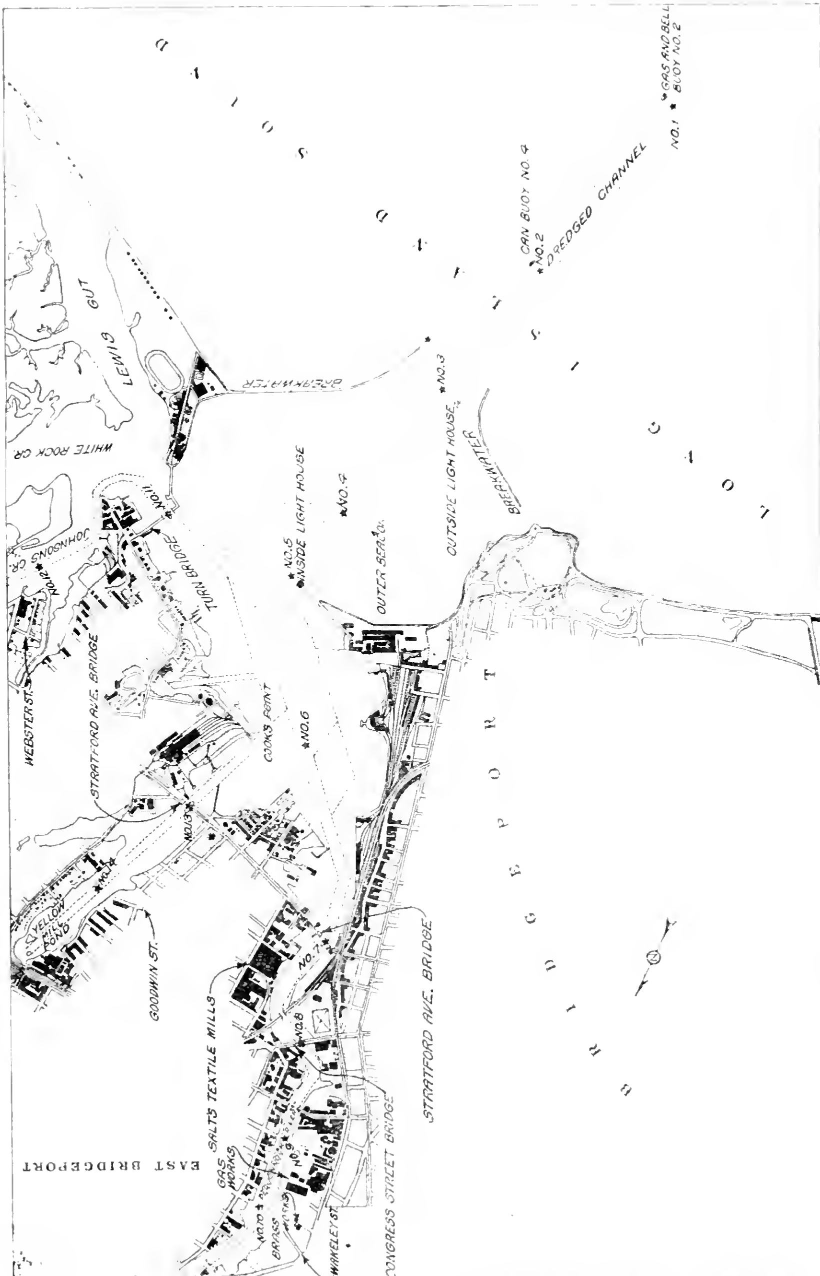
The Bureau of Fisheries requested the coöperation of the Bureau of Chemistry in a study of industrial wastes at West Point, Virginia, on the York River, and at Bridgeport, Connecticut, on Long Island Sound. This work was instituted primarily to ascertain, if possible, by chemical means, the extent of the pollution with sewage and industrial wastes, and its relation to the fish and shell fish industries. These places were selected for study because they offered peculiar advantages for investigation of trade waste, and because numerous complaints had been made by oystermen and others regarding existing conditions. A fairly complete study of the York River situation was made and a report of the work will be submitted at a later date.

BRIDGEPORT, CONNECTICUT, HARBOR.

The population of Bridgeport, Connecticut, is given in the 1920 census as 143,152.

The harbor proper (see Fig. 1) is approximately one and one-half miles long, one-half mile wide at the upper end and one mile wide at the harbor entrance. A channel dredged to from 17 to 21 feet in depth extends down the harbor and about one mile beyond the outside breakwaters. The Pequonnock River, a small stream, flows into the upper end of the harbor, and a small shallow body of water, known as the Yellow Mill Pond, is connected with the harbor at the upper end. An estuary, known as Johnson's Creek, is located at the lower end of the harbor. This estuary is not of much importance from the standpoint of a sanitary survey, the only industrial establishment of any magnitude on this stream being the Lake Submarine Corporation. The city sewage and numerous industrial effluents are discharged into the Pequonnock River, the Yellow Mill Pond and harbor proper. Two series

FIG. 1.



Map of Bridgeport, Conn., narbor and environs, showing location of sampling stations.

of breakwaters have been placed in the harbor. One breakwater extends from the west shore about midway of the harbor proper, the other extends out from both the east and west shores at the lower end of the harbor.

A preliminary study of the Bridgeport Harbor was made on October 16 to 18, 1918, and samples of trade wastes and harbor samples were collected for field and laboratory examinations. This work was repeated on May 20 and 24, 1919, and on September 16, 1919. Mr. J. W. Sale, accompanied by Dr. E. P. Churchill or by Mr. J. S. Gutsell, of the Bureau of Fisheries, conducted the field work. A power boat for collecting samples and the services of an engineer were furnished by the Connecticut Oyster Farms Company, through their Bridgeport manager, Captain C. S. Wheeler. The samples were examined in the field and in the Water and Beverage Laboratory of the Bureau of Chemistry.

SEWAGE IN BRIDGEPORT HARBOR.

Four series of samples were collected from both near the top and near the bottom in the channel of Bridgeport Harbor proper, Johnson's Creek, Yellow Mill Pond, and the Pequonnock River. The sampling stations, the locations of which are shown on the map appended (Fig. 1) were from one-eighth to one-quarter mile apart. A description of the sampling stations and other data of interest are contained in Table I. Dissolved oxygen was determined on these samples in the field. This part of the work was designed to show the extent of the sewage pollution of the harbor and environs at different seasons of the year. One hundred and ten samples of this kind were collected, and the results obtained have been plotted in Fig. 2, by means of which the results of the entire study of dissolved oxygen may be seen at a glance.

Table I.

Location of Sampling Stations, Bridgeport (Conn.) Harbor and Environs.

Station No.	
1	Long Island Sound off gas and bell buoy No. 2.
2	Long Island Sound off can buoy No. 4.
3	Off outside lighthouse, between breakwaters.
4	Off beacon between outside and inside lighthouses.
5	Off inside lighthouse.
6	Off Cook's Point.

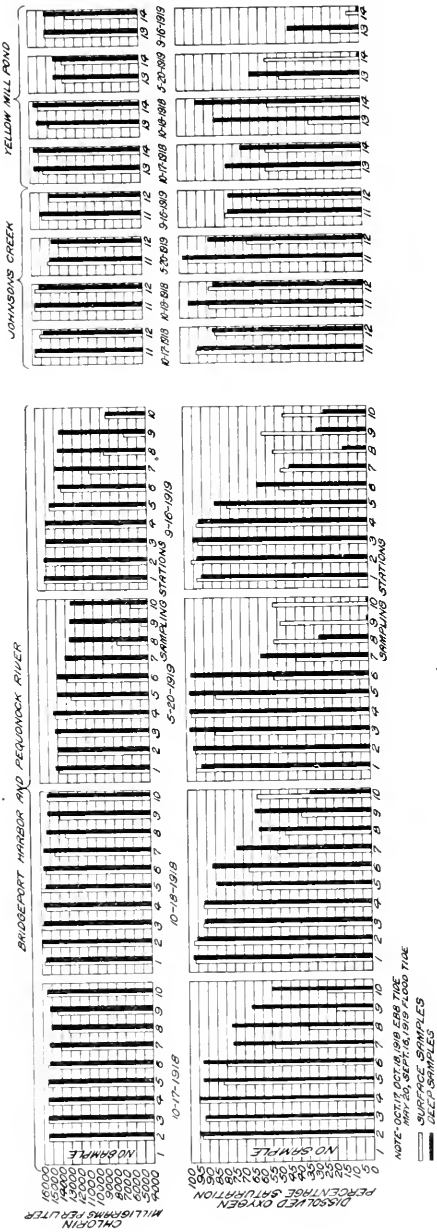
7 At Stratford Ave. Bridge, Pequonnock River.
8 At Congress St. Bridge, Pequonnock River.
9 Off gas works, Pequonnock River.
10 Off Wakeley St., Pequonnock River.
Johnson's Creek.
11 At turn bridge.
12 Off Webster St.
Yellow Mill Pond.
13 At Stratford Ave. Bridge.
14 Off Goodwin St.

On October 17, 18 (1918) the tide was receding and on May 20 and Sept. 16 (1919) the tide was flooding when the samples were collected. On Oct. 17, 18 (1918) and May 20 (1919) the temperature of the samples varied from 12°C. to 17°C. and on Sept. 16 (1919) from 19.5°C to 22°C. The deep samples were collected at depths of from 8 to 30 feet. The percentage of sodium chloride in all samples varied from 0.78 to 2.70.

DISCUSSION OF OXYGEN DATA.

For the purpose of considering the dissolved oxygen content, the harbor environs may be divided arbitrarily into five sections; namely, the wind swept portion in Long Island Sound extending about a mile beyond the outside breakwaters, the lower harbor, including the area between the outside and inside breakwaters, the upper harbor including the area between the inside breakwater and Stratford Avenue bridges, the estuary of the Pequonnock River, the Yellow Mill Pond, and the estuary of Johnson's Creek. Fourteen samples were collected from the area beyond the outside breakwater at sampling stations numbers 1 and 2. This section is beyond the area materially affected by sewage and fairly represents the character of Long Island Sound water in this vicinity. The average dissolved oxygen content of both surface and deep samples was 95 per cent. saturation, maximum 97 per cent., and minimum 90 per cent. These figures may be accepted as a standard with which to compare the dissolved oxygen content of the other areas. Proceeding into the harbor, the area between the outside and inside breakwaters, which has been designated above as the lower harbor, contained an average of 93 per cent. saturation dissolved oxygen, maximum 98 per cent., minimum 84 per cent, 16 samples from the stations numbered 3 and 4 being represented. Proceeding further up the harbor, the area between the inside breakwater and Stratford Avenue Bridge, which has been called the upper harbor, contained an average of 77 per cent. saturation dissolved oxygen, maximum 98 per cent., minimum 48 per

Fig. 2.



Graphic presentation of dissolved oxygen and of chlorin content of samples.

cent., 16 samples from stations numbered 5 and 6 being represented. The estuary of the Pequonnock River contained an average of 13 per cent. saturation dissolved oxygen, maximum 77 per cent., minimum 00. per cent., 32 samples from stations numbered 7, 8, 9 and 10 being represented. This area called the estuary of the Pequonnock River is in reality a part of the upper harbor. The water is salty, containing on an average of 2.0 per cent. sodium chloride, the area beyond the outside breakwater containing about 2.5 per cent. sodium chloride. The Yellow Mill Pond contained an average of 44 per cent. saturation dissolved oxygen, maximum 90 per cent., minimum 00. per cent., 16 samples from stations numbered 11 and 12 being represented. Johnson's Creek contained an average of 81 per cent. saturation dissolved oxygen, maximum 97 per cent., minimum 56 per cent., 16 samples from stations numbered 13 and 14 being represented. As the sources of pollution are approached the dissolved oxygen content decreases as follows, 95, 93, 81, 77, 44 and 13 per cent., these figures representing averages of numerous samples, collected at different seasons and at varying tides. Dissolved oxygen was absent part of the time in the estuary of the Pequonnock River and in the Yellow Mill Pond. When dissolved oxygen is exhausted in water containing much organic matter, active decomposition sets in with the production of hydrogen, methane, sulphide of hydrogen, etc., which condition is characteristic of sewage septic tanks. At various points in the Pequonnock River and the Yellow Mill Pond, bubbles of gas breaking on the surface of the water were noticed, indicating septic decomposition of the sewage sledge deposited on the bottom. The estuary of the Pequonnock River is nearly always highly discolored, especially in the vicinity of Salts' Textile Mills, from which flow great quantities of purple effluents. Above Stratford Avenue Bridge in the Pequonnock River and above Stratford Avenue Bridge in Yellow Mill Pond, visible evidence of fæcal pollution is abundant. During the summer months the odor from these waters is nauseating. However, as mentioned above, a very marked improvement in the appearance and character of the water is evident as one proceeds out into the lower harbor. This improvement undoubtedly is due to the fact that the organic matter dissolved and suspended in the city sewage is rapidly precipitated out when the sewage mixes with the salt water of the Pequonnock River estuary, the upper harbor and the Yellow Mill

Pond. The precipitated material which is highly decomposable, remains on the bottom in the vicinity of the sewer outlets in a relatively small area instead of being distributed over a larger area where it might come into contact with and be purified by the highly oxygenated sea water coming in with the tides from Long Island Sound. This precipitation of dissolved and suspended organic matter in sewage by salt water is an interesting physical phenomenon which we have discussed quite fully in a previous publication,[1] and which must be given consideration in connection with a study of Bridgeport Harbor. The sewage deposit in the Pequonnock River estuary and in the Yellow Mill Pond is quite evidently not swept out to sea, as one might be led to believe by an inspection of the chart of the harbor; on the contrary, such sewage sludge as may be dislodged from the bottom is carried back and forth within a limited area by the action of the tides. It seems probable that the inside breakwater at sampling station 5 (see Fig. 1) tends to prevent the outflow of the polluted water of the inner harbors, but it is believed that the difference in quality between the waters of the Pequonnock River estuary and the Yellow Mill Pond and those of the lower harbor and beyond is due chiefly to the precipitation by salt water of sewage solids in a coherent mass near the sewer outlets.

There is, therefore, a marked contrast of conditions, from a sewage standpoint, rather than a gradual change of condition. This is shown by the drop in dissolved oxygen content from 77 per cent. to 44 per cent., and 13 per cent., respectively, and by the physical appearance of the areas compared. The estuary of the Pequonnock River and the Yellow Mill Pond at the time of this investigation were veritable septic tanks, whereas the harbor outside of Cook's Point (station No. 6) was in fairly satisfactory condition. It should be stated that since this investigation was made, a sewage disposal plant, which clarifies the sewage by means of fine screens, has been installed. This plant is designed to take care of the sewage from the section of the city lying west of the Pequonnock River, which has an estimated population of 100,000, and will ultimately reduce the number of sewage outlets from about 57 to 2. The operation of this plant should materially improve the objectionable conditions described above.

[1] The Vertical Distribution of Dissolved Oxygen and the Precipitation by Salt Water in Certain Tidal Areas, J. FRANKLIN INST., Dec., 1917.

INDUSTRIAL WASTES IN BRIDGEPORT HARBOR.

The analyses of industrial wastes flowing into Bridgeport Harbor from nine sewers are set forth in Table 2. Altogether, the effluents from twenty-one sewers were analyzed, but the effluents from only nine sewers were found to contain unusual ingredients. A description of the location of the twelve sewers not included in Table 2 is as follows: (10) At Berkshire Coal Docks, on west side of Pequonnock River, about 100 yards below dam; (11) off plant of Armstrong Manufacturing Company, on east side of river, between Maple Street and Barnum Avenue; (12) Housatonic Avenue, sewer on west side of Pequonnock River at Washington Avenue Bridge; (13) weir of Bridgeport Illuminating Company, on west side of river; (14) Congress Street sewer under Congress Street Bridge, on west side of Pequonnock River; (15) ten-inch sewer underneath piling off Salts' Textile Mills, on east side of Pequonnock River; (16) Remington Arms Company's weir at upper end of Yellow Mill Pond; (17) off plant of Holmes and Edwards Silver Company, at upper end of Yellow Mill Pond; (18-19) two six-inch sewers off British-American Munition Works, on northwest side of Yellow Mill Pond; (20) large sewer off British-American Munition Works, on northwest side of Yellow Mill Pond; (21) weir at American Tube and Stamping Company (steel works), in Bridgeport Harbor, below Stratford Avenue Bridge.

The effluents from the nine sewers, the composition of which is set forth in Table 2, are objectionable because of the presence of metals, color, or acid. Those containing relatively large amounts of these ingredients are seven in number, and appeared to come from two sources only; namely, the manufacturing establishments of the Bridgeport Brass Works, situated on the west side of the Pequonnock River estuary, and the Salts' Textile Mills, situated on the east side of the Pequonnock River estuary. Great variation is to be expected in the composition of individual samples collected directly from sewer outlets, and the data obtained on the seven sewage effluents mentioned above do vary greatly. At times, relatively large quantities of copper, zinc, acid, color, etc., are shown to be present, while at other times these objectionable ingredients are either absent or present in greatly reduced amounts.

TABLE II

Analysis of Sewer Samples, Pequonnock River and Yellow Mill Pond, Bridgeport, Conn.

No.	Location	Total Solids Ignited	Alkalinity as Bicarbonate HCO_3	Acidity as Sulphuric Acid H_2SO_4	Milligrams per liter except chloride: Iron Fe	Copper Cu	Aluminum Al	Manganese Mn	Lead Pb	Zinc Zn	Arsenic As
1-3	Pequonnock River: Off Bridgeport Brass Works (west side of river). About one hundred yards below new bridge. Three sewers close together.										
	2 ft. dia. Oct. 16, 1918, W.L. 994	21915	114		2.5(*)	0.0		0.0	1.3	26.	0.02
	May 24, 1919, W.L. 755	56	20		.5	0.0	1.4	0.0	0.0	0.	0.00
	Sept. 16, 1919, W.L. 924	15288		304	3.0	240.2	3.3	.08	0.0	40.	
	8 in. dia. Oct. 16, 1918, W. L. 995	288		46	.4(*)	65.		0.0	1.9	9.	0.00
	Sept. 16, 1919, W.L. 925	19620	104		.6	.1	.9	.06	0.0	0.	
	6 in. dia. Oct. 16, 1918, W.L. 996	800		232	11. (*)	18.5		.08	1.0	0.	0.00
4-5	Pequonnock River: Off Bridgeport Brass Works (west side of river). Two fourteen-inch sewers located one hundred yards below the sewers mentioned above.										
	North Oct. 16, 1918, W.L. 997	578	28.		1.6(*)	0.0		.2	.31	21.	0.00
	Sept. 16, 1919, W.L. 928	456	30.		19.5	118.0	9.9	.08	0.4	83.	
	South Oct. 16, 1918, W.L. 998	1025	68.		62.4(*)	18.3		0.0	.27	101.	0:00
	Sept. 16, 1919, W.L. 927	396	24		2.5	2.4	1.7	.17	0.0	0.	
6	Pequonnock River: Twelve-inch sewer a few feet below Congress St. Bridge (east side of river).										
	Oct. 16, 1918, W.L. 1003	471			1. (*)	2.0		0.0	0.0	0.	0.03
	May 24, 1919, W.L. 756	147	139		2.5	0.0	4.8	.02	0.0	0.	0.00
	Sept. 16, 1919, W.L. 926	892	232		3.8	.2	3.8	0.0	0.0	0.	

7	Pequonnock River. Surface sewer located about twenty-five yards below preceding sewer, held in place by posts.										
	Oct. 16, 1918, W.L. 1004....	1188	273(‡)		14.1	0.0		.2	0.0	0.	0.14mg.
	May 24, 1919, W.L. 757....	190	96		.6	0.0	4.8	0.0	.2	trace	.00
	Sept. 16, 1919, W.L. 929....	804	85		5.2	2.3	3.2	.08	0.0	0.	
8	Pequonnock River: Two foot sewer off Salts' Textile Mills (east side).										
	Oct. 16, 1918, W.L. 1005....	273(†)			1.2(*)	0.0		0.0	0.0	0.	0.00
	May 24, 1919, W.L. 758....	32(†)	15		.3	0.0	9	0.0	0.0	0.	0.00
	Sept. 16, 1919, W.L. 931....	3260(†)	85		.6	1.2	1.1	0.0	0.0	c.	
9	Pequonnock River: South end of Salts' Textile Mills (east side of river). About one hundred yards below preceding sewer.										
	Oct. 16, 1918, W.L. 1006....	533(†)			6. (*)	4.0		.2	0.0	0.	
	May 24, 1919, W.L. 759....	1321	215		3.3	0.0	3.0	0.0	0.0	0.	0.00

(*) Fe and Al as Fe. (†) Effluent colored deep purple. (‡) 40 m. p. l. CO_3 found.

EFFLUENTS IN VICINITY OF THE BRIDGEPORT BRASS WORKS, AND ELECTROLYTIC RECOVERY OF COPPER AND SULPHURIC ACID.

The effluents from the sewers in the vicinity of the Bridgeport Brass Works were found to contain acid, copper, and zinc in relatively large amounts. One sample contained 240 milligrams of copper per liter, another 118 milligrams per liter, another 65 milligrams per liter, and two others 18 milligrams per liter, each. One sample contained 101 milligrams per liter of zinc, and five others 83, 40, 26, 21 and 9 milligrams per liter, respectively. Three samples contained mineral acid, which, expressed as sulphuric acid, amounted to 304, 232 and 46 milligrams per liter, respectively.

The other samples in this group were alkaline. Several samples contained small quantities of lead and manganese. Where the samples were acid, the copper and zinc were present chiefly in solution in the effluent. Where the samples were alkaline, the copper, zinc and lead were found chiefly in the sediment which settled out in the bottles after the samples were collected. For example, in W. L. No. 924 (see Table 2, Nos. 1-3) the filtered sample, which was acid, contained 240 milligrams per liter of copper and 40 milligrams per liter of zinc. The sediment contained only 0.2 milligrams per liter copper and no zinc. However, in W. L. 928 (see Table 2, Nos. 4-5) the filtered sample, which was alkaline, contained no copper or zinc, and the sediment derived from one liter of effluent contained 118 milligrams copper, 83 milligrams zinc and 0.4 milligrams lead. In Table 2 the analyses of the supernatant water and of the sediment have been reported together. A composite sample, consisting of six individual top and bottom samples, which were collected from the channel of the Pequonnock River (1, off Gas Works; 2, at Congress Street Bridge; and 3, at Stratford Avenue Bridge), was analyzed. 0.8 milligrams per liter copper found. It is an interesting fact that the oysters grown in the vicinity of Bridgeport Harbor have a puckery taste and a greenish color. With regard to the mineral acid present in these effluents, it should be noted that all of the 110 samples of water collected from the Pequonnock River estuary, and the harbor, were alkaline, showing that the quantity of acid in the effluents was not sufficiently large to overcome the natural alkalinity of the harbor water during the period of observation.

The metals were removed from the acid samples quite effectively (over 99 per cent.) by adding soda ash or lime water in slight excess in the acid followed by filtration. This appears to be a fairly simple method of chemical treatment. In the preliminary investigation, we did not inspect the factories or study the method of production of the objectionable effluents, but in the summer of 1920, the question of the recovery by electrolysis of copper and acid from the effluents was taken up with the officials of the Bridgeport Brass Company, and in January, 1921, the installation of an experimental recovery tank was completed. During the spring of 1921 a number of experimental runs were made. We are indebted to the Bridgeport Brass Company for the following data on this reclaiming tank.

The acid liquor from four pickling tanks is subjected to continuous electrolysis in a lead-lined recovery tank, divided into three compartments. The liquor is circulated through the five tanks by a motor driven pump. The electrodes consist of 96 sheets of copper and lead, each of which are 28 inches long and 30 inches wide, set longitudinally in the three compartments of the tank. In an experimental run May 5, 6 and 7, 1921, two compartments of the tank were connected in series, the copper plates used having an area available for deposition of copper of 300 square feet. The liquor was circulated by the pump at the rate of 4 gallons per minute, the power delivered to the motor generator was 15,400 watts (230 volts x 67 amperes). The power delivered to the recovery tank was 6600 watts ($5\frac{1}{2}$ volts x 1200 amperes), showing an efficiency of 42.8 per cent. One hundred and sixteen pounds of copper and 180 pounds of acid were recovered during the run of 44 hours. The cost of the current delivered to motor generator at 2 cents per kilowatt hour was \$13.55. The motor driven pump used \$1.32 worth of current, making total cost of current used during the test \$14.87. The 116 pounds of copper recovered at 12 cents a pound, was worth \$13.92, and the 180 pounds of regenerated sulphuric acid, at $1\frac{3}{4}$ cents per pound, was worth \$3.15, a total of \$17.07. The profit, therefore, on this experimental run, without figuring in overhead expense, amounted to \$17.07 less \$14.87, or \$2.20. The proposition viewed from a strictly commercial standpoint is therefore not very encouraging, although it is hoped that a better utilization of the current, which is the chief item of expense, can be obtained. No great trouble is antici-

pated in overcoming certain other difficulties which have been encountered: namely, fuming of the solution and the overflow when bundles of tubes are dipped in the pickling tanks. Reclaiming processes of a similar nature are in operation in the plants of the Chase Companies, Inc., of Waterbury, Connecticut, and of the Westinghouse Electric and Manufacturing Company, of East Pittsburgh, Pennsylvania. At the latter place, one pound of copper per kilowatt hour is recovered.[2]

The effluent containing copper and acid which flows into the harbor is derived chiefly from wash tanks in which bundles of tubes which have been pickled are rinsed off. The effluent contains some overflow from the pickle tanks also. The effluent from four wash tanks amounts to about 5400 gallons per hour which contains, according to the officials of the Bridgeport Brass Works, 9 pounds of copper and 40 pounds of sulphuric acid.

EFFLUENTS IN VICINITY OF SALTS' TEXTILE MILLS.

Four of the effluents from the vicinity of Salts' Textile Mills coming from two sewers were dyed a deep purple. These effluents stained the harbor for a long distance, and are of greater importance from the standpoint of appearance of the harbor than any other effluent. There is probably no other type of effluent that arouses the resentment of people so quickly as that which is highly colored, even though it may be harmless. The actual quantity of dye present may be very small, yet the effect very marked, as is the situation at Bridgeport. An effluent of this type ought to be decolorized before being discharged into the harbor. A small quantity of bone charcoal was placed in a filter, some of the effluent passed through in the cold and a water white filtrate was obtained. Treatment with nascent chlorine or calcium hypochlorite was not so effective in decolorizing the effluent.

CORRECTIVE MEASURES.

Very small quantities of unusual ingredients are present in some of the other samples. However, those discussed above are so much worse than the others which were sampled that they have been given first consideration. If the trade wastes which are discharged into the harbor by the Bridgeport Brass Company and by

[2] *Transactions Am. Electrochem. Soc.*, 32 (1917) (Preprint).

the Salts' Textile Mills were treated before being dicharged in the harbor, undoubtedly the conditions other than those due to sewage would be greatly improved. For this reason we hope that the experiments in progress on the recovery of copper and acid may prove to be sufficiently profitable to warrant purification of all effluents which contain copper or acid.

CONCLUSION.

The need of an adequate sewage treatment plant at Bridgeport, Connecticut, is clearly shown by the data contained in this report, and it is gratifying to those interested in preserving the natural beauty of the harbors along the Atlantic Seaboard and in the conservation of our natural resources, that the city of Bridgeport is taking active steps in remedying the conditions set forth herein. The coöperation of one of the principal industrial plants which produces noxious effluents has been secured also, with a view to installation of adequate effluent treatment.

Chrome Ores of Southeastern Pennsylvania and Maryland.—The deposits of chromite in the serpentine belt of southeastern Pennsylvania and eastern Maryland have been studied by ELEANORA B. KNOPF (*U. S. Geological Survey Bulletin 725 B*, 85–99 (1921)). Chrome ore was discovered in Maryland as early as 1827; and that state and Pennsylvania furnished the world's supply of the ore until 1860. Since that year Turkey has been the chief source of chromite. The chrome mining industry of the eastern states has been dormant since 1882; and the domestic production of this ore has practically been confined to the Pacific coast. In the deposits of Pennsylvania and Maryland, chromite occurs as rock ore and in alluvial sand. The rock ore may be in either massive or granular form, and is found in serpentinized pyroxenites and peridotites. The ore is of good quality, containing from 48 to 63 per cent. of chromium sesquioxide. The ore occurs at intervals in a belt which extends for a distance of 50 miles from the southwestern corner of Chester County, Pennsylvania, to the neighborhood of Baltimore, Maryland. At least twelve abandoned mines and prospects exist along this belt; they were closed because of a decline in price, rather than because of exhaustion of the ore. During the war, on account of the demand for chromite, two of these mines were reopened, and preparations were made to concentrate the disseminated ore. Isolated deposits of chromite also occur in Delaware County, Pennsylvania, and have been worked to a small extent. J. S. H.

Some Mechanical Curiosities Connected with the Earth's Field of Force. W. D. LAMBERT. (*Am. J. Science*, Sept., 1921.)—If the earth were a sphere of uniform density with no rotation about any axis, its field of force, due to attraction according to the inverse square law, would be a rather simple affair. It is not a sphere but a mildly bulging spheroid and it has, to complicate matters further, a rotation about an axis, which brings into play at every point a force that must be compounded with that other force there caused by attraction before we can know the intensity and the direction of the force of gravity at that point. The force of gravity is the resultant of the two forces mentioned.

The author discusses the form of equipotential or level surfaces outside of the earth. At a considerable distance above us the level surface is shaped somewhat like that made by placing two equal and thick plano-convex lenses with their flat surfaces in contact. There is a distinct edge to this surface above the equator of the earth. Lower down the level surfaces cease to display this edge. They are in addition not similar to one another, being farther apart at the equator than at the poles. A level surface 1000 metres above sea-level at the equator is about 5 metres nearer to the level of the sea at the pole. A concrete illustration of this is the fact that the northern end of the surface of Lake Michigan, taken as undisturbed by waves, temperature or flow, is 8 cm. nearer to sea-level than the southern end.

A vertical line at any point is the direction of the force of gravity there and is perpendicular to the level surface passing through the point. Such a line, cutting all the level surfaces it meets orthogonally, is not a straight line, but is curved with its convexity toward the equator. "The astronomical latitude of a place is defined as the angle which the vertical at that place makes with the plane of the equator. Evidently then the latitude at the top of a high tower is greater than the latitude of its base."

If the continents are regarded as huge floating bodies projecting above the surfare of the supporting, denser liquid, then there will be a slow motion toward the equator, generally accompanied by a twist of the direction of greatest length. The torsion balance of Eötvös not only indicates but even measures such peculiarities in the gravity field of force as tend to shift the position of continents. Certain results obtained by the use of this instrument are closely dependent on the density and form of the adjacent portions of the earth, and accordingly the balance has been used to search for lignite in Austria.

"The form of a level surface near the surface of the earth has been appropriately compared to that of a withered apple, which, considered as a whole, has a regular curvature, but which, taken in detail, is characterized by minute elevations and depressions."

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SPECIFIC VOLUME OF LIQUID AMMONIA.[1]

By C. S. Cragoe and D. R. Harper, 3rd.

[ABSTRACT.]

The paper is a detailed description of a laboratory measurement, with very high precision over a considerable temperature range, of the specific volume of pure anhydrous liquid ammonia under the pressure of saturation at each temperature. This is one of the series of measurements of the physical properties of pure ammonia in progress at the Bureau of Standards for the purpose of compiling a standard ammonia table for use by the refrigeration industry.

Four glass picnometers of about 5 cm^3 capacity were calibrated with water and mercury to an accuracy of a few parts in a hundred thousand. The temperature coefficient of expansion of the glass was obtained from a determination with an interferometer of the coefficient of linear expansion. The expansion of the picnometers with pressure was determined experimentally, using a liquid of known compressibility.

Seven samples of ammonia, purified by four somewhat different methods, were used in these picnometers, and volume measurements were made throughout the temperature interval -78 to $+100°$ C. Special tests showed less than 1 part in 10,000 (by volume) of noncondensing gases present, and less than 0.01 per cent. (by weight) of other impurities.

The picnometers, after being partially filled with liquid ammonia, were immersed in a thermoregulated bath, the temperature of which could be maintained constant to about 0.01° C. Readings at various temperatures were then taken of the position of the ammonia meniscus in the calibrated capillary of the picnometer. Readings were taken at 5-minute intervals for a period of about ½ hour in order to insure equilibrium.

The total mass of ammonia in each picnometer during any series of measurements was always determined afterwards by

* Communicated by the Director.

[1] Scientific Paper, No. 420.

weighing the picnometer filled with ammonia, then breaking the tip and reweighing, filled with dry air. In the latter series, the total mass was also determined before filling the picnometers, using a small auxiliary bulb soldered to a steel valve. The mass so determined agreed with the subsequent determination to better than 1 part in 10,000.

The picnometers were so designed as to make the mass of the vapor phase small in comparison with the total mass of ammonia. The values of the specific volume of the saturated vapor which enter as a correction term were obtained from preliminary measurements made at this Bureau. In the interval + 50 to + 100° C., these values were obtained by extrapolating the mean diameter of the temperature-density dome.

An empirical equation was found which represents closely the results of the temperature range covered experimentally and also conforms to what is known about the behavior of liquids at the critical temperature. The average deviation of all the measurements from this equation is 1 part in 10,000, and the maximum deviation is 4 parts in 10,000.

As a final result, the specific volume of saturated liquid ammonia is expressed by the equation

$$U=\frac{4.2830+0.813055\sqrt{133-\theta}-0.0082861\ (133-\theta)}{1+0.424805\sqrt{133-\theta}+0.015938\ (133-\theta)}$$

where U is expressed in cubic centimeters per gram and θ in degrees Centigrade.

WAVE-LENGTHS LONGER THAN 5500 A IN THE ARC SPECTRA OF YTTRIUM, LANTHANUM, AND CERIUM AND THE PREPARATION OF PURE RARE EARTH COMPOUNDS.[2]

By C. C. Kiess, B. S. Hopkins and K. C. Kremers.

[ABSTRACT.]

PART I of this paper, by C. C. Kiess, contains the results derived from a study of the yellow, red, and infra-red regions of the arc spectra of yttrium, lanthanum, and cerium. Spectrograms were photographed, with the dyes pinacyanol, kryptocyanin, and dicyanin. The chemicals studied were derived from two sources:

[2] Scientific Paper, No. 421.

From the University of Illinois were obtained the oxalates of yttrium and lanthanum and the oxide of cerium, prepared under the direction of Professor B. S. Hopkins; from Eimer and Amend were obtained the chlorides of yttrium and lanthanum and the nitrate of cerium, the last being a Kahlbaum preparation. In addition to spectrograms of the above named materials secured with the concave grating spectrograph of the Bureau of Standards there were available for measurement two spectrograms made by Doctor Eder, of Vienna, with his grating spectrograph. These spectrograms were of yttrium and cerium salts prepared by C. Auer von Welsbach. The tables submitted herewith contain about 175 lines in the spectrum of yttrium, 410 in the spectrum of lanthanum, and about 1700 in that of cerium. Many of the wave-lengths are those of heads of bands which are prominent in the spectra of yttrium and lanthanum.

Part II of this paper, prepared by Professors B. S. Hopkins and H. C. Kremers at the University of Illinois, describes the methods used in purifying the samples of yttrium, lanthanum and cerium, which were used in this work.

The rare earth compounds prepared at the University of Illinois were derived from two general sources: (1) 182 kilograms of sodium rare earth sulfate, donated by the Welsbach Company, from which were extracted compounds of cerium, samarium, lanthanum, neodymium and gadolinium; (2) 10 kilograms of Norwegian and 100 kilograms of Texan gadolinite, together with 55 kilograms of purchased oxalate which had been prepared from xenotime, from which were extracted compounds of yttrium, dysprosium and erbium.

From the Welsbach residue cerium was removed by boiling the solution to precipitate basic ceric nitrate. This was purified by repeating this process and by several precipitations with oxalic acid.

After the removal of the cerium, samarium was concentrated at the soluble end of a magnesium double nitrate series of fractional crystallizations. The magnesium double nitrate fractionation was repeated first in water and then in 30 per cent. nitric acid. Bismuth was now added and the fractionation continued until the samarium was free from other rare earth salts.

Lanthanum, which concentrated at the insoluble end of the magnesium double nitrate series, was freed from praseodymium and neodymium by crystallization of the double ammonium

nitrate, this process being continued until all absorption bands disappeared from the solution.

For the preparation of neodymium the middle fractions of the magnesium double nitrate series were selected and the fractional crystallization continued until lanthanum and praseodymium were concentrated at the insoluble end while samarium, gadolinium and europium were found at the soluble end. The middle fractions contained very pure neodymium.

Gadolinium was obtained from the fractions at the soluble end of the magnesium double nitrate series. Samarium was nearly all removed by adding bismuth magnesium nitrate. Further purification was accomplished by several precipitations with oxalic acid, but the best gadolinium so far prepared contains a small amount of samarium and terbium and traces of europium.

The yttrium group compounds were prepared mainly from gadolinite which was pulverized, dissolved in HCl, the silica removed and rare earths precipitated by oxalic acid. The oxalates were converted to sulfates and the cerium group elements removed by the addition of Na_2SO_4. The yttrium group material was converted to the bromates and subjected to a long series of fractional crystallizations. Those fractions richest in yttrium were brought together and treated by the method of fractional precipitation, using K_2CrO_4 as a precipitant. The best fractions obtained by this method were then precipitated fractionally with 0.01 N ammonia. The purest materials obtained in this manner were further purified by the sodium nitrate method of fractional precipitation. The material prepared in this manner showed very faint holmium lines when viewed through a 5 cm. layer of concentrated solution; it probably contained not more than 0.005 per cent. of holmium and was reasonably free from other earths.

Dysprosium was removed from the main bromate series, fractionated further as bromates, then converted to the ethyl sulfate and fractionated for a long time in absolute alcohol. This removed the neodymium and praseodymium but there still remained some terbium and holmium, even in the best fractions.

The erbium-rich fractions were likewise removed from the main bromate series, and were further fractionated as the bromates. The fractions containing nothing but yttrium and erbium were further purified by the basic chloride method of Drossbach, the cobalticyanide method of James and Willard, and the sodium

nitrite method of Holden and James. Each of these methods concentrated the erbium but not as rapidly as the nitrate fusion method. The best erbium fractions available contained considerable yttrium and probably small amounts of other rare earths.

FRICTION AND CARRYING CAPACITY OF BALL AND ROLLER BEARINGS.[3]

By H. L. Whittemore and S. N. Petrenko.

[ABSTRACT.]

THE experiments were undertaken by the Bureau of Standards at the suggestion of the Navy Department to determine the maximum safe load and static friction under load of ball and flexible roller bearings.

Tests were made on balls of 1.00, 1.25 and 1.50 in. diameter in grooved straight races with the ratio of groove and ball radii 1.03 and 1.10; 1.04 and 1.12; 1.04 and 1.12 respectively.

The rollers 1.25 in. in diameter and 5.25 in. long were tested in flat and cylindrical races; the inner cylindrical races having radii 3.5 and 10 in. and those of the outer races 4.75 and 11.25 in. respectively.

The scleroscope hardness of balls and ball races was about 65, that of rollers 70 and of the roller races 97.

METHOD OF TEST.

A.—Friction Test.—Two balls were used in the static friction test to secure stability in the loaded condition. The test was made in a 50,000 pound Riehlé machine; the starting effort was determined with a spring balance. One of the two races was movable and rested on rollers, whose friction was determined separately. No lubricant was used during the test.

Similar tests were made on the rollers, using steel plates. In addition, the cylindrical races were fitted to a 230,000 pound Emery testing machine. Two rollers diametrically opposite were used, being held in position by retainers having the same axis of rotation as the inner race.

The torque necessary to rotate the system was determined by a spring balance acting on a lever attached to the inner race.

B.—Compression Test.—To measure the total deformation of a ball (or roller) and two races, an apparatus was designed con-

[3] Technologic Paper, No. 201.

sisting of a simple lever system. The relative displacement of the longer arms which was proportional to the total deformation of the races and the ball was measured by micrometer microscopes. A deformation of 0.00001 in. could be measured. A similar device was used in determining the deformation of rollers.

To determine the contact area between the race and the ball (or roller) an extremely thin film of lubricating oil was applied to the surface of the race, while the ball was dry. The contact surface was distinctly visible as it appeared darker than the surrounding surface. Its diameters were measured by a micrometer microscope.

CONCLUSIONS.

Friction Test.—1. The starting friction is nearly the same for both sizes of groove. The groove having the larger radius gave the lower value.

2. The ratio of starting friction to load (0.00055) is nearly the same for all three sizes of balls and increases slowly with the load (more rapidly for small size ball) until the "critical" load is reached, when the increase becomes rapid.

The critical load varies with the diameter of ball; 1300 lb. for 1.00 in.; 1700 lb. for 1.25 in. and 2200 lb. for 1.50 in. balls.

3. A similar "critical" load, 25,000 lb., was found for the larger roller bearings with a ratio of friction to load equal to 0.00075.

4. This "critical" load at which the friction began to increase more rapidly was in all cases lower than the safe load as determined by permanent deformation and as calculated from Stribeck's law.

Compression Test.—5. The results of compression tests of balls and rollers agree roughly with Hertz's theory. The differences are ascribable to inhomogeneity of the material. The total deformation of ball (or roller) and races follows pretty closely the law of a straight line.

The smaller diameter of contact area agrees with that given by Hertz's theory, the other diameter differs considerably. This is due to the fact that the major diameter of the area of contact is not as assumed by the theory, very small in comparison with the diameter of the ball.

6. The permanent set of a ball is quite negligible even for very high loads (10,000–30,000 lb.) which produce large permanent sets in the races.

7. The permanent set of the ball races increases very gradually; there is no indication of a load below which no set occurs. With a sufficiently accurate measuring device, the permanent set of races may be discovered at a very low load, below that used in actual practice. The load limit depending upon permanent set of races may be arbitrarily assumed.

8. A flexible roller does not produce any appreciable permanent set of races unless stressed beyond its proportional limit, which is about 130,000 lb. This limit tends to decrease as the radius of races increases. The breaking load of the rollers was about 190,000 lb.

RECOMMENDED SPECIFICATIONS FOR PNEUMATIC TIRES, SOLID TIRES, AND INNER TUBES.[4]

These specifications cover the requirements for pneumatic tires, solid tires and inner tubes.

They are a revision of those prepared by the Bureau and now used by the War Department, the Navy Department, the General Supply Committee, the Post Office Department, the Panama Canal, and the Treasury Department. They were recommended by the U. S. Inter-departmental Committee on Specification Standardization, June 8, 1921.

A tentative draft of the specifications was submitted to a large number of representatives of the tire industry, including the Rubber Association of America, and in the revision careful consideration was given to their recommendations.

These specifications are divided into three parts, pneumatic tires, solid tires and inner tubes, and contain a detailed description of the physical and chemical requirements.

Some of the requirements for pneumatic tires are:

The various kinds of fabrics used in the manufacture of a tire are specified as to the length of staple, weight, and tensile strength. For fabric tires the carcass must be made from standard square-woven tire fabric having 23 ± 1 threads per inch in warp and filling. The staple must be not less than 1¼ inches long. The tensile strength of both warp and filling shall be not less than 185 lb. per inch of width. For cord tire fabric the staple shall be not less than 1¼ inches long for all sizes of tires through 5 inch, and 1½

[4] Circular, No. 115.

inches long for the larger sizes. The tensile strength is governed by a strength factor, which varies according to the size of the tire and is determined from the average tensile strength of single cords, the number of cords per inch, and the number of plies. The number of plies required depends on the size of the tire.

The friction compound shall be made from a compound containing not less than 85 per cent. by volume of the best quality, new wild or plantation rubber. The adhesion requirements are: The friction shall be not less than 15 lb. between the plies of a fabric tire and 18 lb. between those of a cord tire; 35 lb. between cushion and breaker, and between tread and breaker; 20 lb. between cushion and carcass; and 14 lb. between sidewall and carcass for fabric tires and 18 lb. for cord tires.

The width and weight of fabric used for the breaker strip depend on the size of the tire, and the staple shall be not less than 1 1/8 inch long.

The compound from which the cushion is made shall be similar to the friction compound. Its thickness and width vary with the size of the tire.

The tread must contain at least 70 per cent. by volume of the best quality new wild or plantation rubber. The organic acetone extract shall not exceed 10.0 per cent., and the total sulphur 9.0 per cent. of the weight of the rubber as compounded. The tensile strength shall be at least 2400 pounds per square inch; the ultimate elongation 500 per cent.; the set, 10 minutes after it has been stretched 400 per cent. for 10 minutes, not more than 25 per cent. Its thickness over all and exclusive of non-skid portion is specified for the different sizes of tires.

The sidewall shall contain at least 65 per cent. by volume of the best quality, new wild or plantation rubber. The organic acetone extract shall not exceed 11.0 per cent., and the total sulphur 9.0 per cent. of the weight of the rubber as compounded. The tensile strength shall be at least 1600 pounds per square inch for all sizes up through 5 inch, and 2000 pounds for the larger sizes; the ultimate elongation 500 per cent.; and the set, 10 minutes after a stretch of 400 per cent. for 10 minutes, not more than 25 per cent. Its thickness varies with the size of the tire.

The bead construction of the different sizes of tires is governed by the reinforcing strips, the weight of these strips and finally by a hydraulic pressure test.

The tire sizes shall conform to the standards established by the Tire Division of the Rubber Association of America. The tires shall fit rims made according to the Tire and Rim Association standards.

Fabric tires under normal conditions of wear and stated S. A. E. loads shall give a mileage of at least 6000, and cord tires 8000.

The requirements for solid tires are briefly: The tread shall be made from a compound containing at least 65 per cent. by volume of the best quality new wild or plantation rubber. The organic acetone extract shall not exceed 10 per cent., and the total sulphur 8 per cent. of the rubber as compounded. Its tensile strength shall be not less than 2000 pounds per square inch; the ultimate elongation 450 per cent.; and the set not more than 40 per cent. 2 minutes after break. It shall be held securely to the base band by a hard rubber base. Other requirements consist of a rebound test, minimum area of cross section and a mileage guarantee of 10,000 under normal conditions of wear and stated S. A. E. loads.

The base bands shall be open hearth steel and conform to certain chemical requirements. They are to be electrically welded and shall give a minimum tensile strength of 45,000 pounds per square inch.

The inner tubes are divided into three classes: Pure gum, red antimony, and compounded tubes. The latter is to be used only in 6-inch or larger sizes.

The analytical and physical requirements are given in the table.

Analytical and Physical Requirements

Class	Rubber by volume Min.	‡Organic acetone extract Max.	‡Total sulphur Max.	(Gypsum) $CaSO_4 \cdot 2H_2O$ Max.	Tensile strength Min.	Ultimate elongation Min.	Set stretch 1 to 6 inch Max.
	per cent.	per cent.	per cent.	per cent.	lb.-sq. in.	per cent.	per cent.
A.....	93	5.0	7.0		1800	750	8
B*....	85	5.0	7.0	7.0	2000	725	10
C†....	80	5.0	7.0		2500	600	15

*This class of tubes shall be compounded only of rubber and antimony sulphide.
†This class of tubes to be furnished only in 6 inch and larger sizes.
‡Based on the weight of rubber as compounded.

In addition the minimum diameter, length, thickness, volume of rubber, and an inflation test for the different sizes of tubes are specified.

Contraction and Expansions of Dental Amalgams.—The amalgams so extensively used in tooth filling are required to have a slight expansion on setting so as to fill the cavity tightly. If not sufficiently expanded the space will be quickly invaded by the fluids and organisms of the mouth, and decay will occur. If the expansion is too great the tooth may be broken. A. W. GRAY communicates to the *Physical Review* (1921, xviii, 108) the results of an extensive study of the properties of amalgams prepared from commercial alloys, and finds much difference in the different samples. The experiments were extended over considerable time. The general opinion is that tin causes contraction and silver expansion. A principal conclusion is as follows:

The contraction found when amalgam from a properly adjusted dental alloy is packed under a very high pressure does not in any way prevent the making of a tight tooth filling, because packing hard enough to cause contraction in such an amalgam will stretch the resilent dentin more than enough to make it follow the slight shrinkage of the filling. In fact, moderate contraction after very tight packing is an advantage, in that it relieves to some extent the straining of the tooth. The tighter the packing, the better the filling, because heavy packing pressure not only adds to the strength of the amalgam, but also shortens considerably the time required for it to complete all its dimensional changes and become stable. Moreover, it secures much better adaptation of the filling to the cavity walls and, consequently, reduces liability to leakage.

The phenomena described are to be expected from a consideration of conditions that influence diffusion, solution, and crystallization. Accurate measurements of the dimensional changes, termed *reaction expansions,* ought to throw light on other problems of metallography and physical chemistry.

H. L.

Production of Organic Compounds by Microörganisms.—In his presidental address entitled "The Laboratory of the Living Organism," DR. M. O. FORSTER, President of the Chemical Section, British Association for the Advancement of Science, pays tribute to the lowly yeast plant and its close relatives, certain bacteria and moulds. Yeast produces glycerol as well as alcohol. *Bacillus macerans* produces acetone and acetic and formic acids. The following organic compounds have also been obtained by the action of microörganisms: Acetaldehyde, dihydroxyacetone, butyl alcohol, butyric, oxalic, succinic, fumaric, lactic, citric, and pyruvic acids. If the proper genus and species of microörganism be chosen and be given the proper food and the proper environment, it will produce the desired organic compound, and will work 24 hours per day. Certain of these microbiological processes are used on a commercial scale, for instance in the manufacture of acetone and butyl alcohol. (*Scientific M.*, 1921, xiii, 301–308.)

J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

ON THE RESTRAINT OF DEVELOPMENT BY BORAX AND CERTAIN SIMILAR SALTS.[1]

By E. R. Bullock.

It is well known that if borax, sodium bicarbonate or ordinary sodium phosphate be added to an ordinary alkaline developer, a restraining effect is produced. Upon repeating experiments on this in the laboratory, using lantern plates, the general results were confirmed. It was found, however, that the restraining effect of borax is more pronounced when the developer has been made up with a caustic alkali instead of with a carbonate and that with a bromided caustic soda hydroquinone developer, the addition of sodium carbonate causes acceleration; that of trisodium phosphate causes acceleration likewise, while sodium succinate has no appreciable effect. Lüppo-Cramer, who originally observed the restraining action of borax in development, concluded that it was due to a tendency to produce an insoluble silver salt, the effect not being given by sulphates, acetates, or tartrates, but only by those acids which form difficultly soluble silver salts, and he expressed the opinion that the principle involved is the same as in the case of restraint by soluble bromides.

The restraining effect of borax, however, and other similar acting salts when added to developers such as hydroquinone containing caustic soda is more easily explicable by the fact that these salts are those which while giving feebly alkaline solutions when dissolved in water, yet diminish the alkalinity of a more strongly alkaline solution. An example of such a salt is sodium bicarbonate. This when dissolved in water under the usual conditions gives a feebly alkaline solution, but when it is mixed with caustic soda, it combines with one chemical equivalent of the latter to form ordinary sodium carbonate, which is much less alkaline than the caustic soda itself, so that the addition of a weak alkali (sodium bicarbonate) to a strong alkali (caustic soda) produces a great

* Communicated by the Director.

[1] Communication No. 127 from the Research Laboratory of the Eastman Kodak Company.

diminution of alkalinity. The case of borax is more complicated in as much as several compounds intermediate in composition between it and caustic soda exist, but borax, although distinctly alkaline when dissolved alone in water, yet greatly diminishes the alkalinity of caustic soda.

The paradox of borax as an accelerator of development in certain cases and as a restrainer in other cases is thus entirely to be explained by changes in active alkalinity produced by the addition of borax to the developing solution. It may be mentioned that since borax has been recommended for use in developers to give a diminished grain that its effect is found to be due entirely to its alkalinity, and that the use of a corresponding developer made up to the same alkalinity with sodium carbonate produces the same effect.

Use of Perchloric Acid in Organic Analysis.—In the analysis of an organic compound, its nitrogen content is usually determined by the Kjeldahl method converting the nitrogen into ammonia by digestion with sulphuric acid, and titrating the ammonia formed. This method is almost universally used in the analysis of foods and of materials of biological origin. The digestion usually requires several hours, even though potassium sulphate be added to raise the boiling point of the sulphuric acid, and cupric sulphate be added as a catalyst. BRAINERD MEARS and ROBERT E. HUSSEY of Williams College (*Jour. Ind. Eng. Chem.*, 1921, xiii, 1054–1056) use 60 per cent. perchloric acid to hasten the digestion. This acid is added to the contents of the flask (sample, sulphuric acid, and cupric sulphate) prior to digestion. The amount of perchloric acid should be so governed that the contents of the flask become clear in not less than three minutes and not more than seven minutes after heating has begun. This result is usually attained if a one-gram sample, one gram of cupric sulphate, 25 c.c. of concentrated sulphuric acid, and 2 c.c. of perchloric acid be used. Digestion must be continued at least 15 minutes after the contents of the flask have become clear. Use of an excessive amount of perchloric acid gives rise to a loss of nitrogen. Distillation and titration of the ammonia are made in the usual way.

J. S. H.

Isomorphism of Sodium Sulphate and Sodium Chromate.—These salts, as dekahydrates, readily form mix-crystals. While the tetrahydrate of sodium sulphate does not exist, THEODORE W. RICHARDS and W. B. MELDRUM, of Harvard University (*Jour. Am. Chem. Soc.*, 1921, xliii, 1543–1545), have discovered mix-crystals of the tetrahydrates of sodium chromate and sodium sulphate. The tetrahydrated chromate crystals dissolve the sulphate as its tetrahydrate to form the mix-crystals. J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COMPOSITION OF CALIFORNIA LEMONS.[1]

By E. M. Chace, C. P. Wilson and C. G. Church.

[ABSTRACT.]

SAMPLES of the Eureka, Lisbon, and Villa Franca varieties of California lemons, from carefully selected trees located in the best lemon-growing districts of the State, were analyzed. The sampling was carried out at monthly intervals through a period of a year, with the following general results.

The differences in specific gravity of the fruit are the most striking of the few well-defined differences found to exist between the varieties examined. The Eureka variety has a greater specific gravity than either of the others; there is no apparent difference between the specific gravity of the Villa Franca and Lisbon varieties.

The Villa Francas contain more oil than the Eurekas. Otherwise, no absolute difference in the oil content is shown, although there is some indication that the Eureka contains less than the other varieties.

There is no difference in the acid content of the three varieties.

A marked difference in the sugar content of the Eureka and Lisbon varieties was shown.

California lemons have the lowest specific gravity during the winter months, and the highest in midsummer. The oil content is lowest in late winter and spring, and highest in the fall. The acidity is highest in the early fall months.

No correlation between the color of the peel and the composition of the fruit was found. As the thickness of the peel increases, the specific gravity of the fruit decreases, as does also the acid content.

No correlation between color and thickness of the peel was shown.

No difference in composition between lemons grown on the coast and those grown in inland valleys was detected.

* Communicated by the Chief of the Bureau.

[1] U. S. Department of Agriculture. *Bulletin 993*, issued October 15, 1921.

ALKALI FUSIONS. III—FUSION OF PHENYLGLYCINE-O-CARBOXYLIC ACID FOR THE PRODUCTION OF INDIGO.[2]

By Max Phillips.

[ABSTRACT.]

A study of the fusion of phenylglycine-*o*-carboxylic acid with potassium hydroxide, sodium hydroxide, and various mixtures of these two alkalies has been made, and the optimum conditions for carrying out this reaction have been determined.

The results of the experiments with potassium hydroxide as the condensing agent indicate that 260° C. is the optimum fusion temperature, 10 minutes the optimum fusion period, and 12 to 16 moles potassium hydroxide to 1 mole phenylglycine-*o*-carboxylic acid, the optimum fusion mixture.

Using sodium hydroxide as the condensing agent, 270° C. has been found to be the optimum temperature, 25 to 30 minutes the optimum time, and 28 to 32 moles sodium hydroxide to 1 mole phenylglycine-*o*-carboxylic acid the optimum mixture.

Potassium hydroxide has been found to give higher yields of indigo than sodium hydroxide.

Mixtures of these two alkalies give better yields of indigo than sodium hydroxide alone, the yield increasing with the increase of the ratio of potassium hydroxide with respect to the sodium hydroxide.

DETERMINATION OF THE MONOAMINO ACIDS IN THE HYDROLYTIC CLEAVAGE PRODUCTS OF LACTALBUMIN.[3]

By D. Breese Jones and Carl O. Johns.

[ABSTRACT.]

The lactalbumin was prepared from fresh skim milk. The casein was first precipitated at 35° C. by normal hydrochloric acid at a hydrogen ion concentration of approximately 4.6. The lactalbumin obtained by boiling the filtrate from the casein for 10 minutes was washed several times with hot water, and dried with alcohol and ether, and finally at 110° C.

The protein was hydrolyzed by boiling for 40 hours with hydrochloric acid (specific gravity 1.1) and the resulting monoamino acids determined, use being made of the more recent methods

[2] Published in *J. Ind. Eng. Chem.*, 13 (1921): 759.

[3] Published in *J. Biol. Chem.*, 48 (1921): 347.

for their separation. After saturating the hydrolysate with hydrochloric acid gas the greater part of the glutamic acid crystallized in the form of the hydrochloride. The diamino acids were then removed from the filtrate from the glutamic acid hydrochloride with phosphotungstic acid, and the solution of monoamino acids subjected to the lime-alcohol method for the separation of the remaining dicarboxylic acids. This removed aspartic acid, hydroxyglutamic acid, and the remainder of the glutamic acid. The monoamino acids recovered from the alcoholic filtrate from the calcium salts of the dicarboxylic acids were extracted with absolute alcohol for the removal of proline, and then esterified according to Foreman's lead salt method. The esters were fractionally distilled under diminished pressure and the amino acids recovered and isolated. Proline was determined in separate hydrolyses according to a method previously published by the authors. Serine was isolated from the unesterified fraction of the monoamino acids. The following percentages of amino acids were obtained: Glycine, 0.37; alanine, 2.41; valine, 3.30; leucine, 14.03; proline, 3.76; phenylalanine, 1.25; aspartic acid, 9.30; glutamic acid, 12.89; hydroxyglutamic acid, 10; serine, 1.76; tyrosine, 1.95.

The outstanding results of this analysis consist in the isolation of 0.37 per cent. of glycine, 1.75 per cent. of serine, and, at least, 10 per cent. of hydroxyglutamic acid. These amino acids have not been heretofore determined in the hydrolysis products of lactalbumin. A yield of 9.30 per cent. of aspartic acid was obtained, which is nine times the amount previously recorded. These percentages, together with those of the other amino acids, are tabulated and compared with the recorded results of a previous hydrolysis of lactalbumin by Abderhalden and Pribram.[4]

PINE-OIL AND PINE-DISTILLATE PRODUCT EMULSIONS: METHOD OF PRODUCTION, CHEMICAL PROPERTIES, AND DISINFECTANT ACTION.[5]

By L. P. Shippen and E. L. Griffin.

[ABSTRACT.]

AN investigation was undertaken to determine the physical, chemical and disinfectant properties of pine-oil and pine-distilla-

[4] *Zeit. Physiol. Chem.*, 51 (1907): 409.

[5] U. S. Department of Agriculture, *Bulletin 989*, issued October 9, 1921.

tion products. The following conclusions were reached as a result of this work:

Pine-oil emulsions made from steam-distilled pine oils, when freshly prepared, gave Hygienic Laboratory coefficients varying from 3.42 to 4.34, the average being 3.88. At the end of twelve months the average was 3.66.

A disinfectant prepared from destructive-distilled pine oil is weaker as well as more variable in its germicidal power against *B. typhosus* than is the Hygienic Laboratory pine-oil disinfectant. The samples examined gave Hygienic Laboratory coefficients of from 1.71 to 3.42.

Emulsions made from the other oils tested gave coefficients under 1. These preparations failed to emulsify completely in 10 per cent. concentration.

Pine-oil emulsions made from various grades of pine oils failed to kill *M. aureus* and *B. anthracis* in any dilution capable of emulsification.

In view of the results obtained these products should not be used for general disinfecting purposes.

When using pine-oil emulsions against *B. typhosus,* it is safer, for practical purposes, to employ a solution of five times the strength capable of killing the organism in five minutes. Thus a product showing by the Hygienic Laboratory method a killing power of $\frac{1}{500}$ should be used in a $\frac{1}{100}$, or 1 per cent., dilution. If a product will not give a dilution having a concentration five times that of the weakest concentration capable of killing *B. typhosus* in 15 minutes, and remain completely emulsified, it should not be used as a disinfectant.

Occurrence of the Aurora Line in the Spectrum of the Night Sky. Lord Rayleigh. (*Nature,* Oct. 13, 1921.)—From exposures made in Essex on 150 nights it is learned that this line can be photographed on two nights out of three without regard to the weather. Strangely enough, twenty-six exposures, made in Northumberland, three degrees nearer to the north pole, gave not a trace of the line, though the same instrument was used in both cases. Seasonal variation cannot be held responsible for the difference since observations at the two stations were made alternately. When a plate was exposed for five nights at the higher latitude the auroral line manifested itself.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, November 16, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1921.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership, since last report, 4.

A report of progress was presented by the Committee on Library.

The Chairman announced that the next business of the meeting would be the presentation of medals and certificates to the gentlemen whose inventions had been examined by the Committee on Science and the Arts and found worthy of recognition by the Institute. He then recognized Mr. W. Chattin Wetherill of the Science and the Arts Committee who introduced His Excellency, James Hartness, Governor of Vermont, recently awarded the Edward Longstreth Medal for his screw thread comparator. Mr. Wetherill said:

Mr. President: It is my very great privilege to present to you His Excellency, James Hartness, Governor of Vermont, the inventor of the Hartness Screw Thread Comparator.

This invention has to deal with the accurate measurement of threaded parts, and when it is realized that by means of threaded parts practically all machinery is held together, any device which can contribute to the accuracy of fit of such machine elements marks a step forward in the safety, dependability and service of machinery in general. The Hartness Screw Thread Comparator is a device by means of which a projection lantern is used to throw an enlarged image of the profile of a screw thread upon a screen. Upon this screen there is a drawing of two perfect screw thread profiles differing from each other by an amount equal to the allowable tolerance. It is, therefore, possible to see at a glance whether the projected profile comes within this tolerance or not. By contrasting this extremely simple method of measurement with the existing methods of gauging and measuring diameters by means of micrometer calipers, it is readily appreciated that this device marks a tremendous step forward.

In consideration of the ingenuity and novelty displayed in the design of this device, and in consideration of its successful development into commercial form, adding as it does another instrument of great value to the mechanic arts, The Franklin Institute, acting through its Committee on Science and the Arts, awards its Edward Longstreth Medal to His Excellency, James Hartness, of Springfield, Vermont, for his Screw Thread Comparator.

The Chairman then presented the Medal and accompanying documents to Governor Hartness who, in acknowledging this recognition, said:

Mr. President, Fellow Members of The Franklin Institute, Ladies and Gentlemen: One of the highest honors that can come to a worker in any field

is a sincere expression of praise by one fully competent. The awards issued by this Institute are of highest significance especially to one who has known the wonderful part the members of the Institute have played in bringing forward this age of Science and highly developed mechanism. It is with a deep sense of appreciation that I accept the Edward Longstreth Medal for invention presented to me by The Franklin Institute. It constitutes at once a token of commendation and an inspiration to further endeavor.

Dr. George A. Hoadley was then recognized and presented Mr. Thomas Willing Hicks of Minneapolis, Minnesota, who had been awarded the Edward Longstreth Medal for his "Once-over" Tiller. Dr. Hoadley said:

Mr. President: While the Committee on Science and the Arts is pleased to recommend the inventor of any useful mechanical device for recognition, it takes especial pleasure in presenting to you the inventor of a device having for its object an increased production from the soil, thus adding to our food supply. The fact that there is a direct relation between the thoroughness with which the soil is prepared for the seed and the quality and quantity of the resulting crop, led the inventor of the "Once-over" Tiller to devise a machine that in a single trip over the land would put it in the best possible condition for production.

Taking the most modern form of plow as a basis he added to it a vertical axis, supplied with steel cutting blades, fixed in such a position that the furrow from the plow would be thrown against these blades. Since the shaft upon which they are mounted rotates at a high rate of speed, the result is that the entire furrow is finely pulverized and ready to feed the rootlets of the growing plant.

In consideration of the invention and development to commercial form of a new and exceedingly useful type of machine for the preparation of a seed-bed for grain or other seeds, The Franklin Institute, acting through its Committee on Science and the Arts, awards its Edward Longstreth Medal to Thomas Willing Hicks, Esquire, of Minneapolis, Minnesota, for his "Once-over" Tiller.

I take pleasure, Mr. President, in presenting Mr. Hicks, inventor of the "Once-over" Tiller.

The Chairman then presented the Medal and accompanying documents to Mr. Hicks, who, in acknowledging this recognition, said:

I am entirely mindful of the great honor which it is my mission here to receive. But I would make it plain that this token of your appreciation is accepted conditionally—that is to say—only will I permit myself to accept the Edward Longstreth Medal after admitting to you and myself the conviction that I was but the channel for the Thought—rather than the creator or originator of it. There is but one creator. I, of myself, gave nothing.

One would be dense, indeed, who did not sense the fact that the world is just now passing through a crucial hour. The bravest are appalled—and inspired—by the present situation and I wonder if you gentlemen of this Franklin Institute fully appreciate the extent to which you are a vital factor in helping to solve the problems now confronting us.

The Franklin Institute of the State of Pennsylvania, by rewarding, recognizing, encouraging and facilitating the art of discovery and invention, makes

it possible for those of us so endowed to manifest new inventions, ideas, plans and methods that, in the end, make us something better than ourselves. I disagree with Cowper; man's first invention was not a stool, but steps—steps hewn in the face of a cliff—and how symbolic is this of our present efforts to mount ever higher.

When Man took the hand of humanity away from the work of Production and lent it, for five long years, to the crime of Destruction—while at the same time increasing Consumption—the world was brought face to face with a condition that called for radical thought and action. The fact that every morning the whole human race wakes up hungry, and the necessity of the farmer producing more food in less time and with fewer facilities—this was the crucible out of which sprang the invention of the "Once-over" Tiller, and for which I am being honored to-night.

We of the great West look to you here of the East, and to you of the New England States to lead the way. Out in our great West country where "main streets" flourish, it is but natural that we turn to you of the older settlements for our examples. We look to the eastern states for initiative and we turn to the New England States for inspiration. We ask to be allowed to continue to hold you up as our ideals.

So, if, in coming down here to receive an honor, I, at the same time bring you a message from "main street" land, let it be this—"Lead on, you of the East and we of the great West will continue to follow; only asking that you continue to lead us ever up."

The President then recognized Mr. L. S. Storrs, President of the Connecticut Company, New Haven, Connecticut, who in presenting a beautifully constructed working model, done to scale, of the original Van Depoele motor said:

The motor of which this is a model was used for hauling freight in the lower Naugatuck Valley, around Ansonia and Derby, to the, so-called, Naugatuck docks connecting with the Naugatuck Valley Steamboat Company which operated a line of steamers between New York and Naugatuck.

The Corporation operating this was known as the Ansonia, Derby and Birmingham Electric Line and was the outgrowth of the original Derby Horse Railway Company.

The original charter of the Derby Horse Railway Company was amended by the Legislature so as to allow the "use of any power except steam," as Mr. John B. Wallace, afterwards the first President of the company, expressed the opinion that it was practicable to operate street cars by electricity.

Definite steps towards actively commencing construction were taken in 1887, $25,000 bonds having been issued.

As appears from its official records, the Derby Company decided to directly purchase its material and equipment and do its own construction work, but the company arranged with a contractor for the entire construction and equipment of its road; who accepted as his compensation, the greater part or all of that company's securities, as such was then common practice in connection with the construction of horse railways in smaller communities.

At the first meeting of the directors held on April 13, 1887, the following resolution was adopted:

"*Resolved*, That the President be authorized to negotiate and make such contract with any company or companies controlling an electrical plan for operating street railways, for the electrical equipment of the road, as is in his opinion most advantageous for the Company."

And a contract was made with the Van Depoele Electric Company in April, 1887 which company for a sum of $20,115 agreed to completely equip the road electrically including setting of poles and stringing wires.

The patents of the company covered "generating and distributing of the current, the transmission and controlling of the same, the constructing of the motors and the various apparatus and devices used in all branches of the electric railway system."

This freight motor arrived in Derby on April 4, 1888 and was described as follows in *The Electrical Review* of April 21, 1888:

"ELECTRIC POWER

"The large electric motor to be used in Ansonia, Connecticut, on the electric road in drawing freight cars has arrived at the station there. It weighs several tons and is enclosed in a neat looking car about eighteen feet in length. Cars can be coupled on at either end and it is arranged to run forwards or backwards. One peculiarity is that the car in which it is enclosed sets down within six inches of the track. It was made at the works of the Pullman Car Company at Pullman, Illinois."

The track and overhead were ready for operation May 1, 1888, and on that date the line was opened, but not with the big motor. Some one had blundered, the roof of the car was too high to let it go under a low bridge near its objective, the steamboat dock. The necessary changes were made at once, the roof dropped two feet; the frame carrying the trolley pole hinged and braced so it could be laid flat on the roof, and to give the operator room. The floor at each side of the motor was dropped and on July 1st the car went into operation.

The motor weighed 17½ tons and was capable of hauling 35 tons of freight.

One or two operating details may be of interest. The commutator bars had fibre separators, at the ends, but under the brushes there were air spaces between. The brushes of laminated copper, covered four bars. Under heavy load there was much arcing which fused the ends of the brushes; and when the car stopped suddenly the armature was apt to turn back a little due to play in the chain, and catching the ends of the brush in the spaces between the commutator bars, crumpled up the leaves. To remedy these troubles the motorman had a hammer and a pair of tinsmith's snips, with which he dressed the brush back into shape.

The motor was in operation up to December, 1888, when the river froze and stopped navigation for these months; on the opening of the river it again went into service, but in October, 1889, the Naugatuck Valley Steamboat Company went out of business and the motor was permanently retired. The passenger cars, however, continued to operate until replaced by later types.

On motion, duly seconded, the thanks of the Institute were extended to Mr. Storrs for his valuable gift.

The paper of the evening was presented by Dr. Heber D. Curtis, Director of the Allegheny Observatory, Pittsburgh, Pennsylvania, on "The Spiral Nebu-

læ and Their Interpretation." The speaker pointed out that of all known classes of celestial objects, the spirals are perhaps the most difficult to fit into any coherent scheme of stellar evolution, either as a point of origin or as an evolutionary product. In form, in distribution, and in space velocity, they stand apart from all other objects observed in the Milky Way. Much modern observational evidence supports the belief that these beautiful objects are separate galaxies of stars, or "island universes," comparable with our own galaxy in size and in number of component suns. Evidence for and against the island universe theory of the spirals was presented. The subject was illustrated by lantern slides.

After a brief discussion the unanimous thanks of the meeting were extended to Doctor Curtis for his interesting communication.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting Held Wednesday, November 2, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, November 2, 1921.

DR. H. J. M. CREIGHTON, *in the Chair.*

The following reports were presented for first reading:

No. 2774. Cipherwriting Typewriter.
No. 2777. Chlorine Distributing Apparatus.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, October 6, 1921, at 8 o'clock. Dr. Gellert Alleman in the Chair. The minutes of the previous meeting were approved as published.

Joseph S. Ames, Ph.D., LL.D., Professor of Physics in the Johns Hopkins University and Director of the Office of Aeronautical Intelligence of the National Advisory Committee for Aeronautics, delivered an address on "Aeronautic Research." The three types of aircraft—airplane, airship, and helicopter—were described. Scientific problems, which arise in connection with the various types, were mentioned; and the mode of solution was outlined. An account was given of wind-tunnel experiments and actual flying tests. The lecture was illustrated with lantern slides.

The paper was discussed. On motion of Prof. Monroe B. Snyder, a rising vote of thanks was extended to Doctor Ames. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, October 13, 1921, at 8 o'clock. Dr. H. J. M. Creighton in the Chair. The minutes of the previous meeting were approved as read.

William Duane, A.M., Ph.D., Professor of Biophysics in Harvard University, presented a communication on "X-ray Spectra and Crystal Structure." The methods for the measurement of X-ray spectra with precision were described. The general character of, and the experimental relations between, continuous, line and X-ray absorption spectra were discussed. An account was given of the evidence obtained through the X-rays concerning the structure of crystals and of atoms, the mechanism of radiation, the quantum law, and the theory of relativity. In conclusion, stress was placed on the importance of spectrum analysis in medical applications of the X-rays.

The lecture was illustrated with lantern slides. After a discussion of the paper, a vote of thanks was extended to Doctor Duane; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, October 27, 1921, at 8 o'clock. Dr. George A. Hoadley in the Chair. The minutes of the previous meeting were read and approved.

Henry Leffmann, A.M., M.D., Ph.D., D.D.S., Lecturer on Research in the Philadelphia College of Pharmacy and Science, delivered an address on "The Application of the Microscope to Research." An account was given of the use of color screens, polarized light, photography with ordinary and special plates, and the staining of minute objects. The lecture was illustrated with lantern slides. The paper was discussed at length; a vote of thanks was tendered Doctor Leffmann; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, November 3, 1921, at 8 o'clock, with Mr. W. C. L. Eglin in the Chair. The minutes of the previous meeting were approved as published.

Fred. H. Albee, A.M., Sc.D., M.D., of New York City, delivered a lecture upon "The Use of Electric Machine Tools in Bone Surgery." The evolution of surgical instruments for the cutting of bone was traced; and an account was given of the construction and use of the automatic machine tools devised by Doctor Albee for use in bone surgery. The tools were exhibited; and lantern slides and moving pictures were used to illustrate the lectures. Doctors Skillern, Young, Albee and others participated in the discussion.

On motion of Doctor Snyder, a rising vote of thanks was extended to Doctor Albee. The meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, November 9, 1921.)

ASSOCIATE.

MR. JAMES STOKLEY, JR., University of Pennsylvania, Philadelphia, Pennsylvania.

NON-RESIDENT.

DR. HARRY S. HOWER, 5709 Solway Street, Pittsburgh, Pennsylvania.
MR. N. M. LOWER, 292 Balph Avenue, Bellevue, Pennsylvania.
MR. EDWARD R. WEIDLEIN, Director of Mellon Institute of Industrial Research, Pittsburgh, Pennsylvania.

CHANGES OF ADDRESS.

MR. J. HOWARD CHAMBERS, 52nd and Media Streets, Philadelphia, Pennsylvania.
MR. F. H. CLARK, 1014 Munsey Building, Baltimore, Maryland.
DR. GEORGE L. KELLEY, 6804 McCallum Street, Philadelphia, Pennsylvania.
MR. HENRY HOBART KNOX, 160 Broadway, New York City, New York.
MR. CHARLES LONGSTRETH, Box 326, Coronado, California.
MR. RICHARD C. MCCALL, 2115 Locust Street, Philadelphia, Pennsylvania.
DR. C. O. MAILLOUX, 111 Fifth Avenue, New York City, New York.
DR. EDWARD MARBAKER, National Lamp Works, E. 45th Street and Hough Avenue, Cleveland, Ohio.
DR. P. G. NUTTING, 109 South Church Street, Schenectady, New York.
MR. JOHN B. RUMBOUGH, P. O. Box No. 2, Ashville, North Carolina.
MR. CHARLES W. SOULAS, 2022 North Park Avenue, Philadelphia, Pennsylvania.
MR. W. E. SYMONS, 108 West 43rd Street, New York City, New York.
MR. EARL H. TSCHUDY, 138 South Fourth Street, Lebanon, Pennsylvania.
MR. J. STEPH. VAN DER LINGEN, Department of Pharmacology, Johns Hopkins Medical School, Baltimore, Maryland.
MR. F. R. WADLEIGH, Fuel Division, Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, District of Columbia.

NECROLOGY.

Joseph William Richards, was born at Oldbury, England, on July 28, 1864, and died at Bethlehem, Pennsylvania, on October 12, 1921. While still a youth he came to the United States with his parents and was educated in the public schools of Philadelphia. He entered Lehigh University in 1886, and completed his education at the University of Heidelberg and the Mining Academy at Freiberg. From 1887 to 1897 he was instructor in Metallurgy and Mineralogy at Lehigh University, later he became asssistant professor, then acting professor and since 1903 has been professor of Metallurgy and Mineralogy in the same institution.

Doctor Richards acted as legal expert in many chemical and metallurgical litigations and was a member of the U. S. Assay Commission in 1897; a member of the jury of awards, and Chairman, Metallurgical Sub-jury Panama

Pacific Exposition, 1915; member, U. S. Navy Consulting Board, 1915-18; a member of the American Electrochemical Society, its first president, 1902, and secretary since 1907.

He was the author of the first English work on aluminum, published in 1887, and numerous other books on metallurgical subjects and a frequent contributor to the technical journals. Doctor Richards was a member of the leading technical societies of the world and became a member of The Franklin Institute on February 2, 1891.

Alexander Gray, Director of the School of Electrical Engineering at Cornell University, and well known as a writer and authority on electrical machinery, died on October 13, 1921, after a lingering illness.

Professor Gray was born in Edinburgh, Scotland, on March 9, 1882. While serving his apprenticeship he attended evening classes at Heriot-Watt College and graduated from Edinburgh University in civil and mechanical engineering in 1903. Awarded a Whitworth Scholarship, he then spent two years at McGill University, Montreal, in the study of electrical engineering.

After graduating from McGill University, Professor Gray joined the engineering staff of the Bullock Electric Company, of Cincinnati, and two years later transferred to the staff of the Allis-Chalmers Company at Milwaukee. During his five years of service with these companies he gained a wide experience in the design, construction and opration of all types of electrical machinery. In 1910 he accepted an appointment as assistant professor of electrical engineering at McGill University. In 1915 he was chosen to fill the position of head of the electrical engineering department in Sibley College, Cornell University. Upon reorganization of the college of engineering at Cornell in 1920, Professor Gray was made Director of the School of Electrical Engineering. A man of fine personality, a charming companion and an exceptionally strong teacher, from the very beginning of his professorship he made a warm place for himself with both students and faculty.

Professor Gray had been granted a considerable number of patents for electrical apparatus. He also contributed largely to the literature of his subject, and his books on electrical machine design, and on the principles and practice of electrical engineering are favorably known to the profession. In 1918 he was the recipient of the Howard N. Potts Medal of The Franklin Institute for his paper on "Modern Dynamo Electric Machinery." Professor Gray was also a member of numerous educational and scientific societies; he took an especially active interest in the work of the American Institute of Electrical Engineers, and served on a number of its technical committees.

In his death, the profession of electrical engineering loses a brilliant engineer and a great writer, and the teaching profession a teacher of rare activity.

Mr. George R. Henderson, Aldine Hotel, Philadelphia, Pennsylvania.

Mr. C. J. Hexamer, The Bartram, Philadelphia, Pennsylvania.

MINUTE OF THE BOARD OF MANAGERS RELATIVE TO THE DEATH OF MR. GEORGE R. HENDERSON.

At the meeting of the Board of Managers, held Wednesday, November 9, 1921, Mr. Coleman Sellers, Jr., addressing the President, said:

It is with sincere regret that the Managers of The Franklin Institute find it necessary to record the death on October 19th last of their fellow member, George R. Henderson.

Mr. Henderson joined the Institute February 23, 1912, and soon connected himself with the Committee on Science and the Arts. During 1914-15, he acted as Chairman of the Committee.

He was elected a manager in 1915, and served continuously from that date until his death.

Mr. Henderson was trained on the Pennsylvania Railroad at Altoona. Then went to the Norfolk and Western Railroad as Assistant to the Superintendent of Motive Power at Roanoke, Virginia. He was promoted to Mechanical Engineer and subsequently appointed Superintendent of Motive Power of the Atchison, Topeka and Santa Fe Railroad. He resigned this position and took up practice as a Consulting Engineer, specializing in railroad work, with offices in New York. He had some very important commissions, including the design and equipment of the railroad shops at Parsons, for the Missouri, Kansas and Texas Railway. He subsequently removed to Philadelphia and accepted a position with the Baldwin Locomotive Works, as Mechanical Engineer. This he retained as long as his physical condition permitted, when he retired from active work.

Mr. Henderson was a mechanical engineer of ability and wide experience, especially in railroad work. He was a well-informed man with a decided interest in science in general, especially in physics and astronomy. Personally, he was cordial, kindly and sociable. He was an attentive and efficient manager and his absence from our meetings will be felt, and his loss sincerely regretted.

The Secretary is requested to convey to Mrs. Henderson an expression of the sincere sympathy of the Managers in her great bereavement.

LIBRARY NOTES.

PURCHASES.

BANCROFT, WILDER D.—Applied Colloid Chemistry; General Theory. 1921.

BARNETT, E. DE BARRY.—Anthracene and Anthraquinone. 1921.

BLYTH, ALEX. WYNTER AND BLYTH, M. W.—Poisons: Their Effects and Detection. 1920.

FIERZ-DAVID, HANS EDOUARD.—Fundamental Processes of Dye Chemistry. 1921.

FISCHER, MARTIN H.—Soaps and Proteins. 1921.

FRIES, AMOS A. AND WEST, CLARENCE J.—Chemical Warfare. 1921.

HALL, WM. T. AND WILLIAMS, R. S.—Chemical and Metallographic Examination of Iron, Steel, and Brass. 1921.

MORECROFT, J. H.—Principles of Radio Communication. 1921.

PRING, J. N.—The Electric Furnace. 1921.

SMITH, ARTHUR BESSEY AND CAMPBELL, WILSON LEE.—Automatic Telephony. 1921.

SNELL, F. D.—Colorimetric Analysis. 1921.

SNELL, JOHN F. C.—Power House Design. 1921.

SVEDBERG, THE.—The Formation of Colloids. 1921.

WHITEHEAD, S. E.—Benzol: Its Recovery, Rectification and Uses. 1920.

GIFTS.

Air Brake Association, Questions and Answers on the U. C. Equipment. New York City, New York, no date. (From the Association.)

American District Steam Company, Bulletins 155 and 156 and Catalogue No. 21. North Tonawanda, New York, no date. (From the Company.)

American Engineering Company, The Central Station and the Taylor Stoker. Philadelphia, Pennsylvania, 1921. (From the Company.)

American Foundry Equipment Company, American Sand Blast Equipment. New York City, New York, no date. (From the Company.)

American Foundrymen's Association, Year Book for 1921. Chicago, Illinois. (From the Association.)

American Institute of Mining and Metallurgical Engineers, Transactions, vol. lxiv. New York City, New York, 1921. (From the Institute.)

American Iron and Steel Institute, Annual Statistical Report for 1920. New York City, New York, 1921. (From the Institute.)

American LaFrance Fire Engine Company, Inc., LaFrance Safety Devices. Elmira, New York, no date. (From the Company.)

American Wood-preservers' Association, Proceedings of the Seventh Annual Meeting. San Francisco, California, January, 1921. (From the Association.)

American Woolen Company, American Woolen Company Mills, Library edition. Boston, Massachusetts, 1921. (From the Company.)

Ashland Fire Brick Company, Refractories for Oil Burning Furnaces. Ashland, Kentucky, no date. (From the Company.)

Ashworth and Parker, La Machine a Vapeur Parker. Bury, England, no date. (From the Company.)

Atlas Car and Manufacturing Company, Catalogue on Cars, Electric Locomotives and Complete Industrial Railway Equipment. Cleveland, Ohio, no date. (From the Company.)

Austin Manufacturing Company, Catalogue G on The Austin Motor Sweeper. Chicago, Illinois, no date. (From the Company.)

Baker, R. and L., Company, Catalogue No. 11 on Industrial Tractors and Trucks. Cleveland, Ohio, no date. (From the Company.)

Bastian-Blessing Company, Catalogue No. 23 of Rego Welding and Cutting Apparatus. Chicago, Illinois, July, 1921. (From the Company.)

Bath, John, and Company, Inc., Bulletins 10, 15 and 20 of Micrometers. Worcester, Massachusetts, no date. (From the Company.)

Belliss and Morcom, Ltd., Fuel Economy. Birmingham, England, June, 1921. (From the Company.)

Blaw-Knox Company, Catalogue No. 23, Blawforms for General Concrete Construction. Pittsburgh, Pennsylvania, no date. (From the Company.)

Braby, Frederick, and Company, Ltd., Booklet on Braby Steel Structures and Handbook for Architects and Engineers. Glasgow, Scotland, no date. (From the Company.)

Brackett, F. W., and Company, Ltd., Air Compressors, Pumps, etc. Colchester, England, 1921. (From the Company.)

British Machine Tool Makers, Ltd., Machine Tools, First Edition. London, England, no date. (From the Company.)

British Scientific Instrument Research Association, Third Annual Report for the Year 1920-1921. London, England. (From the Secretary.)

Brown Brothers, Ltd., Catalogue of Electric Lighting and Starting Equipment for Motor Vehicles. Birmingham, England, no date. (From the Company.)

Brown Clutch Company, Hoists. Sandusky, Ohio, no date. (From the Company.)

Brown Hoisting Machinery Company, Catalogue K, Locomotive Cranes and Booklet on Man Power Multiplied. Cleveland, Ohio, 1921. (From the Company.)

Brown University, Catalogue 1920-1921. Providence, Rhode Island, December, 1920. (From the University.)

Browning Company, Browning Buckets. Cleveland, Ohio, 1918. (From the Company.)

Brunton's Alternating Stress Testing Machine. Musselburgh, Scotland, June, 1921. (From Brunton's.)

Buckton, Joshua, and Company, Ltd., Catalogue of Machine Tools and Testing Machines. Leeds, England, no date. (From the Company.)

Bucyrus Company, Hydraulic Dredges, Bulletin H-101. South Milwaukee, Wisconsin, no date. (From the Company.)

Bury Compressor Company, Bulletin No. 407 on Air Compressors. Erie, Pennsylvania, no date. (From the Company.)

Butters Brothers and Company, Catalogue No. 51 of Cranes. Glasgow, Scotland, no date. (From the Company.)

Calebough Self-Lubricating Carbon Company, Inc., Catalogue No. 6 of No-Spark Brushes. Philadelphia, Pennsylvania, 1921. (From the Company.)

Canada Grand Trunk Railway, Annual Report for 1920. Montreal, Canada. (From the Company.)

Chisholm-Moore Manufacturing Company, Catalogue 26 of Hoists. Cleveland, Ohio, no date. (From the Company.)

Cleveland, Cincinnati, Chicago and St. Louis Railway Company, 32nd Annual Report of the Board of Directors. Cincinnati, Ohio, 1920. (From the Directors.)

Cleveland Crane and Engineering Company, Catalogue No. 2 on Cranes. Wickliffe, Ohio, no date. (From the Company.)

College of William and Mary, Catalogue 1920-1921. Williamsburg, Virginia, April, 1921. (From the College.)

Columbia University, Catalogue 1920-1921. New York City, New York. (From the University.)

Conradson Machine Tool Company, Contract Work. Green Bay, Wisconsin, no date. (From the Company.)

Cutler-Hammer Manufacturing Company, Booklet on Elevator Controllers. Milwaukee, Wisconsin, no date. (From the Company.)

Dayton-Dowd, Bulletin 244 on Centrifugal Pumps. Quincy, Illinois, no date. (From the Company.)

DeLaval Separator Company, Catalogue No. 200 of DeLaval Method of Centrifugal Clarification of Varnishes, Japans and Pigment Goods. New York City, New York, no date. (From the Company.)

DeLaval Steam Turbine Company, Ten Years Progress in Water Works Pumps. Trenton. New Jersey, 1921. (From Dravo-Doyle Company.)

Detroit Stoker Company, Booklet on Detroit Stokers. Detroit. Michigan, no date. (From the Company.)

Diamant Tool and Manufacturing Company. Inc.. Circular on Diamant Dies. Newark, New Jersey, 1921. (From the Company.)

Dickinson College, Catalogue 1920-1921. Carlisle, Pennsylvania. (From the College.)

Dow, Charles Mason, Anthology and Bibliography of Niagara Falls. Vols. i and ii. Albany, New York, 1921. (From New York State Library.)

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Edwards, O. M., Catalogue H, Trap-Doors and Fixtures, and Catalogue W-19, Window Fixtures. Syracuse, New York, no date. (From the Company.)

Electric Controller and Manufacturing Company, Bulletins 1033A and 1042A. Cleveland, Ohio, July, 1921. (From the Company.)

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Farrell-Cheek Steel Foundry Company, The Illustrated Story of a Farrell-Cheek Steel Casting. Sandusky, Ohio, no date. (From the Company.)

Fisher Governor Company, Bulletin Catalogue on Power Plant Specialties and Catalogue T-19 on Steam Traps. Marshalltown, Iowa, no date. (From Sheffler-Gross Company, Philadelphia Representatives.)

Fry's Metal Foundry, Fry's White Metals. London, England, no date. (From the Company.)

Fuerst-Friedman Company, Price list of Motors. Cleveland, Ohio, no date. (From the Company.)

General Fireproofing Company, Saving with Shelving and Efficient Record Protection. Youngstown, Ohio, no date. (From the Company.)

Geometric Tool Company, Booklet on Geometric Screw Cutting Tools and Machines, fifth edition. No date. (From the Company.)

Georgetown University, General Catalogue, 1920-1921. Washington, District of Columbia. (From the University.)

Glover, W. T., and Company, Ltd., List No. 14, Glo-clad Electric Wiring System. Manchester, England, March, 1921. (From the Company.)

Good Roads Machinery Company, Inc., Champion Snow Plow. Kennett Square, Pennsylvania, no date. (From the Company.)

Goucher College, Catalogue for 1921-1922. Baltimore, Maryland. (From the College.)

Griscom-Russell Company, Bulletin No. 1140 on Stratton Steam Separators. Philadelphia, Pennsylvania, no date. (From the Company.)

Gwynnes, Ltd., Modern Centrifugal Pumping Machinery and Circulars Nos. 83, 84, L515, L518, L535, L539. London, England, no date. (From the Company.)

Hagan Corporation, Hagan De-Concentrator. Pittsburgh, Pennsylvania, no date. (From the Corporation.)

Hart Roller Bearing Company, Two booklets, Prepare for a Boom and Increasing Production. Orange, New Jersey, no date. (From the Company.)

Haverford College, Catalogue 1920-1921. Haverford, Pennsylvania, 1921. (From the College.)

Haverhill Engineering Department, Annual Report of the City Engineer. Haverhill, Massachusetts, 1921. (From the Department.)

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Heap, Joshua, and Company, Ltd., Catalogue of Screwing Machines and Tools. Ashton-under-Lyne, England, 1921. (From the Company.)

Holcroft's Steel Foundry Company, Ltd., Concerning Steel Castings. London, England, no date. (From the Company.)

Hunton, C. A., and Sons, Handy Machines and Twist Drills. London, England, no date. (From the Company.)

Hyatt Roller Bearing Company, Report on Trucks. New York City, New York, no date. (From the Company.)

Ideal Electric and Manufacturing Company, Bulletins 101 and 105 on Elevator Motors. Mansfield, Ohio, no date. (From the Company.)

Ingersoll-Rand Company, "Little David" Pneumatic Tool Accessories. New York City, New York, May, 1921. (From the Company.)

International Harvester Company of America, International Motor Trucks for Passenger Service and Road Work. Chicago, Illinois, no date. (From the Company.)

International Railway Fuel Association, Proceedings of the Eighth, Ninth, Tenth and Eleventh Annual Conventions, 1916-1919. Chicago, Illinois. (From the Association.)

Insley Manufacturing Company, Catalogue No. 43. Indianapolis, Indiana, no date. (From the Company.)

Iron and Steel Institute, Journal, vol. ciii, No. 1, Charter, By-Laws and List of Members and Associates. London, England, 1921. (From the Secretary.)

Jeffrey Manufacturing Company, Catalogue No. 350 on Jeffrey Material Handling Machinery. Columbus, Ohio, no date. (From the Company.)

Jointless Fire Brick Company, Modern Furnace Building. Chicago, Illinois, 1921. (From the Company.)

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Leathers Company, Ltd., Booklet on Hydraulic Leather Users. Manchester, England, no date. (From the Company.)

Lehigh University, Register, 1921. Bethlehem, Pennsylvania. (From the University.)

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Locomotive Stoker Company, The Duplex Locomotive Stoker. Pittsburgh, Pennsylvania, no date. (From the Company.)

Lonergan, J. E., Company, Catalogue No. 200 on Boiler, Steam and Gas Engine Fittings. Philadelphia, Pennsylvania, no date. (From the Company.)

Lussky, White and Coolidge, Inc., Catalogue E on Cabinet Hardware. Chicago, Illinois, 1918. (From the Company.)

Lynn Water Supply Commissioners, Report for 1920. Lynn, Massachusetts. (From the Commissioners.)

Manchester Association of Engineers, Transactions, 1919-1920. Manchester, England. (From the Secretary.)

Manley Manufacturing Company, Bulletins 61 and 62, Vises. York, Pennsylvania, no date. (From the Company.)

Massachusetts Institute of Technology, Catalogue on Courses of Study and Subjects of Instruction and General Information Requirements for Admission, First and Second Editions. Cambridge, Massachusetts, 1921. (From the Institute.)

Master Tool Company, Catalogue and Price List of Master Tool Reclaiming System, Their Parts and Appliances. Cleveland, Ohio, no date. (From the Company.)

Mechanical Appliance Company, Bulletins 401 to 405, inclusive, on Watson Motors. Milwaukee, Wisconsin, no date. (From the Company.)

Medford Water and Sewer Commissioners, Annual Report. Medford, Massachusetts, December, 1920. (From the Commissioners.)

Merchants Association of New York, Year Book, 1921. New York City, New York. (From the Association.)

Michigan Central Railroad Company, Seventy-fifth Annual Report. Detroit, Michigan, 1921. (From the Company.)

Michigan College of Mines, Year Book 1920-1921. Houghton, Michigan. (From the College.)

Modern Engine and Supply Company, Catalogue No. 21. Chicago, Illinois, 1921. (From the Company.)

Morse Dry Dock and Repair Company, Keeping the World's Ships in Good Condition. Brooklyn, New York, 1921. (From the Company.)

Nash Engineering Company, Bulletins Nos. 10, 11, 15, 16 and 17. South Norwalk, Connecticut, 1919. (From the Company.)

National Carbon Company, Inc., Catalogue No. 37 on National Carbon Brushes. Cleveland, Ohio, 1921. (From the Company.)

National Hoisting Engine Company, Catalogue on Hoisting Engines, Sixth Edition. Harrison, New Jersey, no date. (From the Company.)

National Malleable Castings Company, Booklet on Anchor Chain Cables. Cleveland, Ohio, no date. (From the Company.)

Nazel Engineering and Machine Works, Nazel Air Hammers. Philadelphia, Pennsylvania, 1921. (From the Works.)

Novo Engine Company, Catalogue No. 921. Lansing, Michigan, no date. (From the Company.)

Ohio State University, Catalogue 1920-1921. Columbus, Ohio. (From the University.)

Oilgear Company, Bulletin 4, Hydraulic Power Transmissions. Milwaukee, Wisconsin, no date. (From the Company.)

Oil, Paint and Drug Reporter, Green Book for Buyers, 1921 edition. New York City, New York. (From the Editor.)

Ontario Hydro-Electric Power Commission, Report on Hydro-Electric Power in the Niagara District. Montreal, Canada, no date. (From the Commission.)

Orton and Steinbrenner Company, O. S. Locomotive Cranes and Grab Buckets. Chicago, Illinois, no date. (From the Company.)

Pantasote Company, Catalogue of Waterproof Fiber Boards. New York City, New York, no date. (From the Company.)

Parson, C. A., and Company, Ltd., Pamphlet No. 3 on Steam Turbines to Paper Mills. Newcastle-on-Tyne, England, no date. (From the Company.)

Pease, C. F., Company, Catalogue of Blue Print Machinery and Drafting Room Supplies. Chicago, Illinois, no date. (From the Company.)

Pennsylvania State College, General Catalogues for 1919-1920 and 1920-1921. State College, Pennsylvania. (From the College.)

Pierce, Butler and Pierce Manufacturing Corporation, Booklet on Pierce Packless Valves. New York City, New York, July, 1921. (From the Corporation.)

Polytechnic Institute of Brooklyn, The Story of the Polytechnic and Its Service to the Public. New York City, New York, 1920. (From the Institute.)

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Purdue University, Test of Road Materials of Indiana. Lafayette, Indiana, January, 1921. (From the University.)

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Rockford Twist Drill Company, Catalogue on Drills. Rockford, Illinois, no date. (From the Company.)

Ruson and Hornsby, Ltd., Oil Engines. London, England, no date. (From the Company.)

Russell and Stoll Company, Bulletin No. 50 on Wiring Fittings. New York City, New York, July, 1921. (From the Company.)

Ryerson, Joseph T., and Son, Ryerson Handbook on Alloy Steels. Chicago, Illinois, 1921. (From the Company.)

St. Louis Water Commissioners, Annual Report for year ending April, 1921. St. Louis, Missouri. (From the Commissioners.)

Sanderson Cyclone Drill Company, Big Blast Hole Drills. Orville, Ohio, 1921. (From the Company.)

Sharon Pressed Steel Company, Sharon Products. Sharon, Pennsylvania, no date. (From the Company.)

Shaw, Francis and Company, Ltd., Rubber and Allied Trades Machinery. London, England, no date. (From the Company.)

Simon-Carves, Ltd., Reinforced Concrete Engineers and Coal Washeries. Manchester, England, no date. (From the Company.)

Southern Railway Company, Twenty-seventh Annual Report. New York City, New York, 1921. (From the Company.)

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Structural Slate Company, Chapters 6, 7 and 8 of a series on Structural Slate. Pen Argyl, Pennsylvania, no date. (From the Company.)

Thermoid Ribber Company, Universal Joints, Their Use and Misuse. Trenton, New Jersey, 1919. (From the Company.)

Thoner and Martens, Catalogue of Disconnecting Switches, Heavy Duty Switches and T and M Seitch Locks. Boston, Massachusetts, no date. (From the Company.)

Thornycroft, John I., and Company, Ltd., Catalogue of Motor Vehicles. London, England, 1920. (From the Company.)

Thwing Instrument Company, Bulletins 10 and 17. Philadelphia, Pennsylvania, 1921. (From the Company.)

Tufts College, Annual Catalogue 1920-1921. Boston, Massachusetts. (From the College.)

Turton Brothers and Matthews, Ltd., Catalogue of Shear Blades, Dies, Punches, etc. Sheffield, England. (From the Company.)

Union University, Announcements from Medical Department, 1915-1921. Albany, New York. (From the University.)

Universal Winding Company, Electrical Coil Winding Machinery. Boston, Massachusetts, no date. (From the Company.)

University of Maryland, Bulletins Nos. 240 and 241. College Park, Maryland, 1920. (From the University.)

University of South Carolina, Catalogue 1920-1921. Columbia, South Carolina, April, 1921. (From the University.)

Ursinus College, Catalogues for 1919-1921. Collegeville, Pennsylvania. (From the College.)

Uskside Engineering Co., Ltd., Three Throw Ram Pumps, Haulage, Mining Plant, Hauling Engines. Newport, England, no date. (From the Company.)

Wallwork, Henry and Company, Ltd., Wallwork Worm Gear Drives. Manchester, England, no date. (From the Company.)

Warren-Knight Company, Sterling Transits and Levels. Philadelphia, Pennsylvania, no date. (From the Company.)

Watts, Fingham and Company, Ltd., Catalogue of Machinery, Tools, etc. London, England, no date. (From the Company.)

Wellesley College, Calendars 1916-1921. Wellesley, Massachusetts. (From the College.)

Wellman-Seaver-Morgan Company, Bulletins 63, 64 and 65 on Hydraulic Turbine Equipment. Cleveland, Ohio, July, 1921. (From the Company.)

Wesleyan University, Catalogues for 1917 to 1920. Middletown, Connecticut, 1917 to 1920. (From the University.)

Wheeler Condenser and Engineering Company, Wheeler Condensers. Carteret, New Jersey, 1921. (From the Company.)

Will Corporation, Abridged Catalogue of Laboratory Apparatus. Rochester, New York, no date. (From the Corporation.)

Williams Tool Corporation, Don't Let it Happen to You. Erie, Pennsylvania, no date. (From the Corporation.)

Wright, Joseph, and Company, Ltd., Booklet on Chains, Slings, Cables and Anchors. London, England, no date. (From the Company.)

BOOK NOTICES.

DIE BINOKULAREN INSTRUMENTE. By Moritz von Rohr. Second edition, with 136 figures, pp. xvii 303, one table. Berlin, Julius Springer, 1920.

This is an amplified and corrected second edition of v. Rohr's book of 1907. The Theoretical Part occupies but a small part of the volume, and deals with the essentials of the theory of binocular vision. The remainder of the work is dedicated to the history of binocular instruments together with the historical evolution of the concepts about the seeing with two eyes, from Euclid (300 B.C.) and the Greek philosopher Artemidor (100 B.C.) up to 1910. The chief publications on binocular vision which appeared since 1910 are tabulated at the end of the volume with reference numbers to the general historical index. The latter (pp. 262-271) will be particularly useful for those who contemplate further special historical studies of the subject.

LUDWIK SILBERSTEIN.

IMPERIAL INSTITUTE. Monographs on mineral resources with special reference to the British Empire prepared under the direction of the Mineral Resources Committee, of the Imperial Institute, with the assistance of the scientific and technical staff. Silver Ores, by H. B. Cronshaw, B.A., Ph.D., A.R.S.M. 152 pages, illustrations, 8vo. London, John Murray, 1921. Price 6 shillings, net.

This is one of a series on mineral resources with special reference to the British Empire. It is, as the title indicates, devoted entirely to silver ores. It contains a very large amount of information concerning the sources of silver, the amount mined and notes of the characters of the ores. The United States produced in 1916 nearly half the silver obtained in the world. A map on the Mercator projection shows the location of all the mines mentioned in the text. Many statistical tables are given, but there is also a large amount of descriptive matter which shows that the author, who was until lately a teacher of geology, has made careful and extensive studies of the regions covered by the essay.

HENRY LEFFMANN.

DIE TECHNIK DER ELEKTRISCHEN MESSGERÄTE. By Georg Keinath, Eng.D. 8vo., vii-443 pages, index and 372 illustrations in the text. R. Oldenbourg, Munich and Berlin. Paper-bound, 112 marks; cloth, 122 marks.

This work has grown out of a lecture delivered before the Electrotechnic Association of the Rhine-Westphalian area, in 1919, in connection with a high school course. The text of this lecture was published and with a view to extend the scope the present volume has been prepared. It covers the technical field only, inasmuch as the majority of available works in this field are not written

by persons actually engaged in the practical side, and, this side has been especially presented, since there are available good works on the side of purely scientific methods. Many forms of apparatus known only in the records of the patent offices have been left unnoticed, and more space has been given to description of the form and construction of the instruments, than to the theoretic questions and mathematical demonstrations. The large use of graphic methods will be acceptable to all users of the volume. The tenor of the descriptions leans somewhat towards the instruments about to come into use, and terms formed in agglutinative method so common to the German language are freely employed. This procedure is rather prominent now in Germany. A strong disposition is manifested to get rid of all terms having a foreign flavor. It is, in the main to be regretted, but it is probably an aftermath of war, and is, fortunately, less serious in the case of the German language because the individual words that are combined in the new terms are generally sufficiently suggestive to enable any one reasonably familiar with the language to work out the meaning. In photography, for instance, "Lichtbild Kunst" and "Lichtbild" have taken the place of "photographic art" and "photograph." In the work before us, we have such terms as "Dreheiseninstrumente," "Nebenwiderstand," "Vorwiderstand," which the author says need no explanation nor justification.

The illustrations are of very high quality. Many of them are from blocks furnished by the manufacturers of the instruments, and as the paper and presswork are both of good quality, the apparatus is shown in clear and distinct form. Apparatus from one firm is especially illustrated, a result, the author tells us largely due to his extensive use of such instruments.

It is not possible to summarize in the space allotted to a review the many excellencies of the book. It is, indeed, astonishing that a nation just emerging from a most disastrous war and burdened with both domestic and international complications, should be able to produce a volume of such an extent and thoroughness. It would seem to include about all that the technical electrical engineer will need in elucidating the construction, principles and operation of the measuring instruments used in the commercial applications of electricity. Incidentally, the author remarks that in the earlier instruments the form of the case was determined by the form of the machinery, but that now-a-days, the machinery is often adapted to the form of the case, a condition which is not always to the advantage of the instrument.

The fundamental considerations of exactness in electrical measuring instruments are, of course, much the same as in all other similar apparatus, but three principal errors are stated and given full consideration, namely: Inherent defects of the apparatus, defect in the method of measurement, errors in reading the results.

The book is commendable in all respects, and really one of the many instances of the extraordinary thoroughness, patience and purely scientific spirit in which the German carries out his task.

HENRY LEFFMANN.

NOS USINES MÉTALLURGIQUES DÉVASTÉES. (Our Devastated Metallurgical Plants.) This quarto volume of over 200 pages with many clear and vivid illustrations is published by La Revue de Métallurgie.

It shows the damage done deliberately to the many industrial plants in France and Belgium during the German occupation. The work has been prepared under the supervision of a group of engineers, an introduction being furnished by Prof. Leon Guillet of the Conservatory of Arts and Trades in Paris.

In the circular accompanying the copy, it is remarked that perhaps some will regard the publication as unnecessary at this late date, as the world has now other troubles and has no time to weep over the deeds of the war-days. The collection of photographs, however, is very instructive and informing as showing the character of modern war when carried out by an enemy that obeys no rule or agreement. The sight of these ruins is very impressive to the French and Belgian peoples and shows that their fear of future war is much more developed in regard to armies than in regard to navies, and explains the anxiety of France in regard to the results of the present conference on the limitation of armaments, which seems to be directing its attention almost entirely to the restriction of the sea-power.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 120. Practical Stability and Controllability of Airplanes, by F. H. Norton. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

The effect of the characteristics of an airplane on balance, stability, and controllability, based on free flight tests, is discussed particularly in respect to the longitudinal motion. It is shown that the amount of longitudinal stability can be varied by changing the position of the center of gravity or by varying the aspect ratio of the tail plane, and that the stability for any particular air speed can be varied by changing the camber of the tail plane. It is found that complete longitudinal stability may be obtained even when the tail plane is at all times a lifting surface. Empirical values are given for the characteristics of a new airplane for producing any desired amount of stability and control, or to correct the faults of an airplane already constructed.

Report No. 122. Preliminary Experiments to Determine Scale and Slip Stream Effects on a 1/24th Size Model of a JN4H Biplane, by D. L. Bacon. 10 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

This work was undertaken at the Langley Field Aerodynamic Laboratory to obtain results on a small model of a complete airplane which might be used for comparison with corresponding tests made in full flight. Somewhat similar tests have been previously made at various other laboratories; but as certain discrepancies exist between corresponding tests in different tunnels, it has been deemed advisable to obtain a direct comparison for this particular installation.

The present work covers tests on a 1/24th scale model at speeds varying from 6.7 m./sec. (15 m.p.h.) to 40.2 m./sec. (90 m.p.h.). A slip stream correction has been obtained by the use of a small belt-driven propeller mounted in front of the model, and force coefficients thus obtained are compared with the measurements of the same forces made in full flight on a geometrically similar airplane.

This report gives lift, drag, and longitudinal moment values obtained in tests of a particularly accurate model over a wide range of speeds. A measure

of the slip stream corrections on lift and drag forces was obtained by the use of power-driven model propeller.

Measurements were also made of forces and longitudinal moments for all angles from 0° to 360°.

PUBLICATIONS RECEIVED.

Eléments d'Analyse Mathématique a l'Usage des Candidats au Certificat de Mathématique Générales des Ingenieurs et de Physiciens. Cours Professé a l'Ecole Centrale des Arts et Manufactures, par Paul Appell. Fourth edition, entirely rewritten. 715 pages, illustrations, 8vo. Paris, Gauthier—Villars et Cie, 1921. Price 65 Francs.

Study Questions in Elementary Organic Chemistry, by Alexander Lowy, Ph.D., and Thomas B. Downey, M.S. 91 pages, 8vo. New York, D. Van Nostrand Company, 1921. [The study questions contained in this work are used in connection with the elementary organic chemistry course given at the University of Pittsburgh. They are based on the contents of a general elementary course. A list of reference books for collateral reading and study is given.]

Machine Drawing. A test and problem book for technical students and draftsmen by Carl L. Svenson, M.E., assistant professor of Engineering Drawing in the Ohio State University. 214 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1921.

U. S. Bureau of Mines. Monthly statement of Coal-mine Fatalities in the United States, August, 1921, by W. W. Adams. 10 pages, 8vo. Technical Paper 249, the Determination of Oxides of Nitrogen by V. C. Allison, W. L. Parker, and G. W. Jones. 13 pages, illustrations, 8vo. Technical Paper 291, Production of Explosives in the United States during the Calendar Year 1920, with notes on mine accidents due to explosives by William W. Adams. 44 pages, illustrations, 8vo. Technical Paper 293, Coke-oven Accidents in the United States during the Calendar Year 1920, by William W. Adams. 32 pages, 8vo. Washington, Government Printing Office 1921.

National Advisory Committee for Aeronautics: Technical Notes No. 65, Langley Field Wind Tunnel Apparatus by D. L. Bacon. 4 pages, illustrations, quarto. No. 71, Experiments with Slotted Wings, translated from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," June 15, 1921. 32 pages illustrations, quarto. No. 72, Aneroid Investigations in Germany, prepared by M. D. Hersey. 9 pages, quarto. No. 73, The Choice of Wing Sections for Airplanes by Edward P. Warner, 30 pages, folded plates, quarto. Washington, Committee, 1921.

Exchange Stabilization. Hearings before the Committee on Banking and Currency of the House of Representatives on H.R. 8404 to investigate the international exchange problem for the purpose of determining the means which may best be employed for the stabilization of exchange, Saturday, October 8, 1921. Statement by Mr. H. N. Lawrie economist, American Mining Congress. 51 pages, tables, 8vo. Washington, Government Printing Office, 1921.

Absolute Sizes of Certain Monovalent Ions, by Wheeler P. Davey. 3 pages, 8vo. Reprinted from the *Physical Review*, N.S., volume xviii, No. 2, August, 1921.

CURRENT TOPICS.

The Limits of the Validity of the Geometrical Law Relating to the Refraction of Light. P. Froelich. (*Ann. der Physik.*, No. 15, 1921.)—Let a ray of light travel through water upward toward air above the water. The geometrical law governing such a case predicts that this ray will emerge into the air or will be totally reflected back into the water according to the size of the angle of incidence. In fact, the matter is not so simple. A more complete theory indicates and experiment verifies that light really does penetrate into the air even when the geometrical law points to nothing but total reflection. The intensity of the light finding its way into the air diminishes rapidly with the depth of penetration.

Let us now consider the case of light originating in air and incident on a surface of water. One ray strikes the surface at right angles and enters with no change of direction. A second ray making an angle of 5° with the first meets the surface at a different point, suffers a change of direction and is continued by a ray of light in the water. A ray the direction of which in air makes 10° with the first encounters the surface of the water at a still different place, there experiences a change in direction greater than that of the second ray and in the water travels in a direction different from that followed in the water by the second ray. As rays farther and farther from the first are traced their points of contact with the water are progressively more distant, the changes of direction at the surface grow greater and greater and the refracted rays within the water make larger and larger angles with a perpendicular to the suface. When the ray in air just grazes the surface the refracted ray makes its maximum angle with the perpendicular. This angle is designated the critical angle.

Within the water let a straight tube be placed in the direction of the first refracted ray. Light from the source in air will come through it and an eye in the water would see the source through the tube. If the tube were shifted to one side and turned so as to lie along the second refracted ray the eye could again perceive the source. So long as the direction of the tube when prolonged to meet the surface makes an angle with the perpendicular there that is not greater than the critical angle it is possible by moving the tube about to find a position at which the source can be seen through it. If, however, the angle be made greater than the critical angle, there is no position at which the source can be seen through the tube. At least there should not be were the geometrical law strictly true, but again here theory and experiment unite to show that the angle may in reality be greater than the critical angle and still the source may be seen

through the tube, provided that the source be very close to the surface of separation.

The purpose of this investigation is to measure the maximum distance of the source from the surface for different departures of the line of sight beyond the critical angle. Glass was used instead of water. The distance from the source to the surface was measured by a method based on Newton's rings. One set of observations was made with green light of wave-length .000522 mm., for which the critical angle of the glass employed was 38.0°. To see the source in air along a line of sight making an angle with the perpendicular to the surface 2.5° greater than the critical angle, the source could not be farther from the surface than 2.51 wave-lengths or .001310 mm. For 40° beyond the critical angle the corresponding quantities are .613 wave-lengths or .000320 mm. With the same angles the distances when red light was used are all larger, though equivalent to a smaller number of wave-lengths.

G. F. S.

On the Variation of Resistance of Selenium with Temperature. SNEHAMOY DATTA. (*Phil. Mag.*, Sept., 1921.)—The curious sensitiveness of selenium to light, which shows itself by an enormous change in electrical resistance when the element is illuminated, has made this substance an important, even an essential, factor in transmitting light effects, such as pictures and photographs, to a distant point. The present investigator sets himself the task of finding how far the change of resistance under illumination is due to a change of temperature caused by the absorption of the incident radiation. The resistances of several selenium cells was measured from 0° C. to 170° C. Above the latter temperature sublimation begins. At 217° C. is the melting point. For one specimen the resistance at zero was 66.0×10^5 ohms, while at 170° C. it was a mere 2×10^5 ohms.

To determine how largely the change of temperature bulks in the change of resistance consequent upon illumination a cell was measured in the dark and its resistance was found to be 67.0×10^5 ohms. It was then exposed to light from which both ultra-violet and infrared wave-lengths had been abstracted. The resistance was then 48.0×10^5 ohms, a decrease of 19×10^5 ohms. A thermo-couple showed that the selenium had risen about one degree. From the previous measurements this elevation of temperature would cause a fall in the resistance of $.75 \times 10^5$ ohms. It thus appears that the heating effect is competent to account for only about one twenty-fifth of the entire change in resistance.

Three different types of selenium crystals were obtained. One variety was "primarily non-conducting," a second was only slightly conducting and on this property change of temperature had no effect. The third type, appearing red in reflected light, was moderately conducting at the temperature of the room. Upon warming the red color gradually vanished and at the same time the resistance grew less. This type of crystal may, therefore, well be responsible for the

resistance change of selenium with rise of temperature. The color change of the crystals points to some sort of a transformation.

G. F. S.

The Age of the Earth. (*Nature,* Oct. 13, 1921.)—A discussion on this subject was held at the recent meeting of the British Association for the Advancement of Science at Edinburgh at which the points of view of physics, geology and astronomy were presented. Lord Rayleigh arrived at the age of uranium-bearing rocks from a study of their amounts of uranium-lead and helium. The rates of transformation from uranium through all the intermediate steps down to lead are known. This is not ordinary lead but lead of atomic weight 206. Assuming that there has been no change in the rates of transformation an age of 925,000,000 years is derived from these rocks. Considerations based on the helium content lead to concordant results. He assigns a period of a few billion years as the duration of the earth's crust in a condition fit for human habitation.

The geologists did not present an undivided front in respect to the proper interpretation of the data of their science. Professor Gregory held that prevalent age estimates might well be multiplied by ten or twenty. Results thus obtained would agree with those emanating from the field of physics.

Eddington from considerations based on certain variable stars concluded that Lord Kelvin's famous time-scale must be multiplied by 700. Jeffreys used two entirely distinct lines of approach, temperature distribution downward in the earth's crust and the evolution of the solar system by tides. In both cases he derives about two billion years as the length of time since the solidification of the crust.

G. F. S.

An Anticipation of One of the Results of Einstein's Theory of Relativity. P. LENARD. (*Ann. d. Physik,* Number 15, 1921.)—Einstein predicted that a ray of light from a star would be deviated from its path when it passes near the sun. This was confirmed by photographs of stars taken a couple of years ago at the time of a total eclipse of the sun. Professor Lenard, who is, to say the least, not strongly prejudiced in favor of the theory associated with the name of Einstein, takes pleasure in directing attention to a forgotten article, published by J. Soldner in 1801. The latter was a German mathematician, born in Bavaria, the son of a peasant. According to Professor Lenard's somewhat caustic comment, "He had besides the advantage of not having attended too many schools." In the article mentioned this scientist of Napoleonic times attributed to a ray of light all the absolute properties of matter and considered it as subject to gravitation. On this basis he calculated the deviation such a ray would experience in passing near the sun and arrived at an expression which Einstein likewise reached more than a century later from considerations of the Relativity Theory.

G. F. S.

Escapements and Quanta. SIR JOSEPH LARMOR. (*Phil. Mag.*, Oct., 1921.)—One outstanding difficulty in the Rutherfordian atom is to account for the emission of radiation from the outer ring of electrons, to explain the continuous emission of energy, if no energy is imparted to the emitting system. With that characteristically British longing for a concrete, material model—a bent that made Faraday regard his lines of force as real, elastic entities, that constrained Lord Kelvin to continue his search for a satisfactory type of ether, and that caused Sir Oliver Lodge to devise the ingenious and illuminating models of his "Modern Views of Electricity"—the Oxford don puts the arousing question "Might not an atom be a clock?" The pendulum of a clock keeps on swinging because at the right time and in the proper quantity it has its energy replenished from an accessible store. It is suggested that the outer electron-system corresponds to the pendulum, and that it is nourished by some kind of sublimated, dynamical escapement system from a stock of energy in the core of the atom. The bowed violin string and the blown organ pipe are invoked by way of illustration. "All which is parabolic, yet to a vivid imagination may be fertile in analogy." In relation to quanta the remark is made, "Wherever it proves necessary in physical science to treat of discrete quanta of energy, it may well be that these are packets separated in the cases concerned by the atomic mechanism —just as period in natural radiation is said in a certain sense to be a creation of the resolving prism or grating—without having to face the difficult assumption that energy is itself necessarily discrete. The quanta of practical physics would of course be large multiples of such packets."

G. F. S.

The Mental Multiplication and Division of Large Numbers. V. A. BAILEY. Queen's College, Oxford. (*Phil. Mag.*, Sept., 1921.)—The man on the street usually regards the methods employed by himself for the performance of the operations of multiplication and division of numbers as established from eternity and immutably derived from the constitution of the human mind. Perhaps more than one member of the A.E.F. was shocked out of his self-complacency to discover small French children doing long division by a way he knew not and by a method he could not at once follow, though he could see that it reduced the time requisite for the process.

The Oxford mathematician here presents a method of multiplication for which he advances the claims that it is speedier than the common methods, that it is less liable to error and that it is less fatiguing for large numbers. He makes very clear each step of the procedure. It is indeed surprising how simple the new method is to learn and how, after a few trials, it competes in quickness with the older method practised for decades.

G. F. S.

Corrosion of Metals in Alkaline Soils.—W. NELSON SMITH and J. W. SHIPLEY presented at the tenth general meeting of the Engineering Institute of Canada, Saskatoon, August 11, 1921, a paper giving an account of extended experiments on the corrosion of metal conduits by soil solutions. The paper appears in full in a recent issue of the *Engineering Institute's Journal*. The conclusions are:

1. The corrosion of cast iron by the salt solutions found in natural soil is readily accomplished under natural conditions without access of stray current. The corrosion is of the so-called graphitic pitting type by which is meant the commonly observed condition of the material remaining in place, which is invariably of a soft spongy texture with part of the iron dissolved out, the remainder resembling graphite in consistency.

2. Magnesium salts are the most corrosive of the soil salts, and magnesium sulphate, which was found wherever a cast iron pipe had been destroyed, is apparently the most effective of the salts experimented with.

3. Local action induced by naturally occurring concentration cells may easily be a factor in the pitting of cast iron exposed to salts of varying concentration.

4. Slight pitting corrosion was found in pieces of cast iron exposed to the action of small samples of wet soil and intermittently heated, even in the short period of forty days, and with only a limited supply of water as compared with conditions in natural ground, no impressed e.m.f. being present.

H. L.

On the Velocity of Sound in Gases at High Temperature and the Ratio of Specific Heats. H. B. DIXON, COLIN CAMPBELL and A. PARKER. (*Proc. Royal Soc.*, A 702.)—The time required for a sound wave to traverse the gas contained in a tube of known length was measured by a pendulum chronograph. The material of the tube was selected so as to avoid chemical action between the contained gas and the tube. For air and carbon dioxide it was desirable to have a tube of fused silica. This was difficult to get since the length was to be 14 meters. The Thermal Syndicate of Newcastle-on-Tyne accomplished the task, and though the first two long tubes coiled into spirals broke in transit and the third broke upon heating the fourth proved satisfactory.

The velocity of nitrogen was measured up to 1000° C. for which temperature the value of 696.8 m. per sec. is given. At 0° C. it is 334.4. The velocity in air was determined up to 700° C., while 600° is the limit for carbon dioxide and methane. From the velocities in the tube the velocities in free air are calculated. The data for specific heats at constant pressure and at constant volume are also tabulated. The ratio of the former to the latter in the case of nitrogen sinks from 1.408 at 0° C. to 1.374 at 1000° C.

G. F. S.

On the Electrical Conductivity of Some Dielectrics. H. H. POOLE. (*Phil. Mag.*, Oct., 1921.)—By means of a transformer and two thermionic rectifying valves the opposite, parallel surfaces of the dielectric were brought to a difference of potential. The current that then passed through the insulator was measured by the deflection of a galvanometer. From the potential difference per unit of thickness and the current the conductivity of the specimen was calculated. In the experiments the difference of potential was progressively raised until the dielectric was punctured. In the case of mica this took place when the potential gradient was about 2.9 megavolts per centimeter. For glass the corresponding number is .6; for paraffin wax, .25; for shellac, from .04 to .25; and for celluloid, .16.

When a conductor of electricity, such as copper, is investigated by the method sketched above it is found that the current flowing through it varies directly as the applied difference of potential. This relation is what is expressed in Ohm's Law. In other words, the conductivity of copper is independent of the current flowing through it and of the difference of potential applied, so long as all other physical properties undergo no change. With dielectrics quite a different relation holds, as Mr. Poole brought out in papers published several years ago. He finds that the higher the applied potential difference the greater is the conductivity. The relation is expressed by the formula $\log K = A + BX$, where K is the conductivity, X the potential gradient, and A and B are constants. Upon plotting X as abscissa and $\log K$ as ordinate, it is seen that for mica and glass at least the curves are nearly straight lines, though in the case of mica in the higher ranges of potential a curvature shows itself. Mica, when tested at different temperatures, presents curves which are parallel to one another, while for glass the slope of the curves changes in a systematic way with temperature. The influence of temperature on the resistivity of mica is enormous. For a certain specimen the resistivity for low potential gradients is 312 times as great at 13° C. as at 128°. Furthermore one specimen of mica shows a resistivity about 100 times that of another specimen, even when conditions are almost alike.

G. F. S.

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